Sky and TELESCOPE

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DECEMBER, 1957

50 cents

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Celestial Mechanics
of Artificial Satellites

Northern and Southern
Star Charts


Celestar
by fecker

Sky and TELESCOPE

CHARLES A. FEDERER, JR., Editor
JOSEPH ASHBROOK, Technical Editor

Vol. XVII, No. 2 DECEMBER, 1957

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COVER: The rocket case of the first Russian artificial satellite, seen descending in the southeast on the morning of October 16, 1957. The one-minute exposure began at 5:03 a.m. Eastern standard time, and was made by John Gregory, Springdale, Connecticut, with a special 3-inch f/1.5 Perkin-Elmer aerial reconnaissance lens stopped to f/3. The film was Royal-X Pan, developed four minutes in DK-60a. The bright star at the left is Alpha Hydrae (Alphard), and the rocket's trail passed close to the star 12 Hydrae.

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Another Russian Satellite

A SCANT MONTH after the first Soviet artificial satellite began circling the earth, it was joined by another. The new object will be known scientifically as Satellite 1957β, if Smithsonian astronomer Fred L. Whipple's proposal for such nomenclature is officially adopted (see page 60).

Popularly known as Sputnik II, the satellite initially completed a circuit of the globe every hour and 43.7 minutes, about 7½ minutes slower than did its predecessor, Satellite 1957α. Its orbit was also larger and more elliptical. At apogee, the new object reached a height of about 1,050 miles above the earth's surface, and at perigee dipped to about 100 miles high. The orbit is inclined approximately 65 degrees to the earth's equator, like that of the first satellite. The initial plane of the second launching did not coincide, however, with the plane of the first satellite's orbit on November 3rd.

According to the official Soviet announcement of the launching, the new satellite had the unexpectedly great weight of 1,120 pounds. It became evident within a few days, however, that this figure represented the conical last stage of the carrier rocket. The 184 pounds for 1957α referred only to the 23-inch sphere; there is no generally available information on the weight of the third stage that accompanied it.

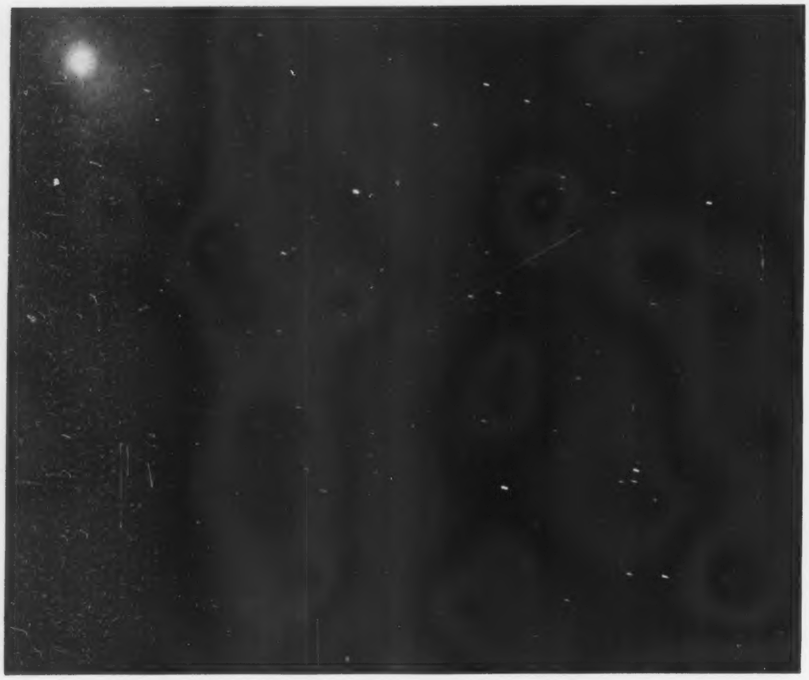
This half ton includes the weight of the shell and of several interior compartments containing instruments. One installation is for the study of primary cosmic rays, which are fast-moving atomic nuclei that are stopped by the denser layers of the atmosphere and produce the secondary cosmic rays recorded at the earth's surface. Other equipment is intended to record the sun's radiation in the ultraviolet and X-ray regions of the spectrum.

Inside an airtight container was the dog that captured headlines throughout the world. This was a laika, a small-boned breed of Eskimo dog. The animal was provided with food, liquid, and air; its heartbeat, breathing, blood pressure, and temperature were being telemetered to the ground.

On the initial revolutions around the earth, 1957β was tracked by American observers by its 40- and 20-megacycle radio transmissions. While these are the same frequencies as for the first moonlet, the latter had been silent for over a week.

As this issue of *Sky and Telescope* goes to press, the first reports have been received of visual observations. The earliest American sighting seems to have been that by the Tucson, Arizona, MOONWATCH team on the morning of November 5th. Next morning Sputnik II was widely seen from the central and western

(*Continued on page 65*)



Earth's natural satellite, the moon, shares the predawn sky of October 16th with the easily seen third stage of the rocket launched by Russia on October 4th. Its trail crosses the star Chi[2] Orionis; stars in Gemini are in the top of the field. Paul Donaldson took this 45-second exposure at about 5 o'clock Eastern standard time, at Arlington, Massachusetts. He used an f/3.5 Super Ikonta IV camera and Tri-X film.

The First Man-Made Satellites

SPUTNIK, first Russian artificial satellite, was launched on October 4th in secrecy, and its early career was marked by an almost complete lack of information as to its physical characteristics.

It is a sphere with a diameter of 58 centimeters (nearly 23 inches), weighing 83.6 kilograms (about 184 pounds). It has a hermetically sealed casing of aluminum, its surface polished and specially treated. Before being launched, the sphere was filled with gaseous nitrogen, according to a news release from *Pravda* on October 9th.

Four metal rods, 2.4 to 2.9 meters long, are attached to the outer surface of the casing. When Sputnik was being carried to its orbit by a three-stage vehicle, the antenna rods were folded against the body of the rocket. When the protective nose cone was jettisoned, and the satellite began its independent motion, the antenna rods opened out on swivels.

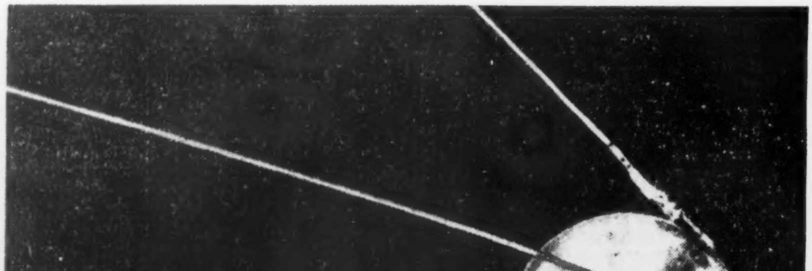
As it moves around the earth, the satellite is periodically subjected to sharp variations of temperature, being heated by the sun's rays while over the daytime side, yet cooled by radiation while on the nighttime side. It is an independent celestial body exchanging heat with surrounding space, and forced circulation of the nitrogen within the sphere plays an important part in maintaining its temperature equilibrium.

The radio signals broadcast on two frequencies carried important scientific information. Sensitive elements recording such things as the satellite's temperature changed the frequency of the telegraphic code, and also varied the ratio between the lengths of the signals and the pauses.

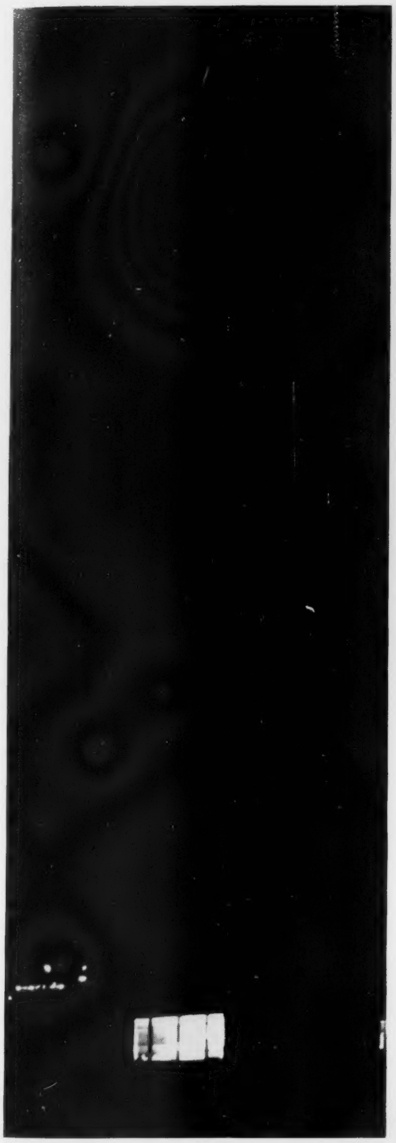
An important part of the satellite's scientific mission was to broadcast, over a considerable length of time, signals that would have to penetrate the layers of the earth's ionosphere from above. In fact, we do not know at present the heights of the uppermost layers: Sputnik was, however, above the layers of maximum ionization, and perhaps above the entire ionosphere. Future satellites will thus undoubtedly add to our knowledge of the propagation of radio energy through the atmosphere.

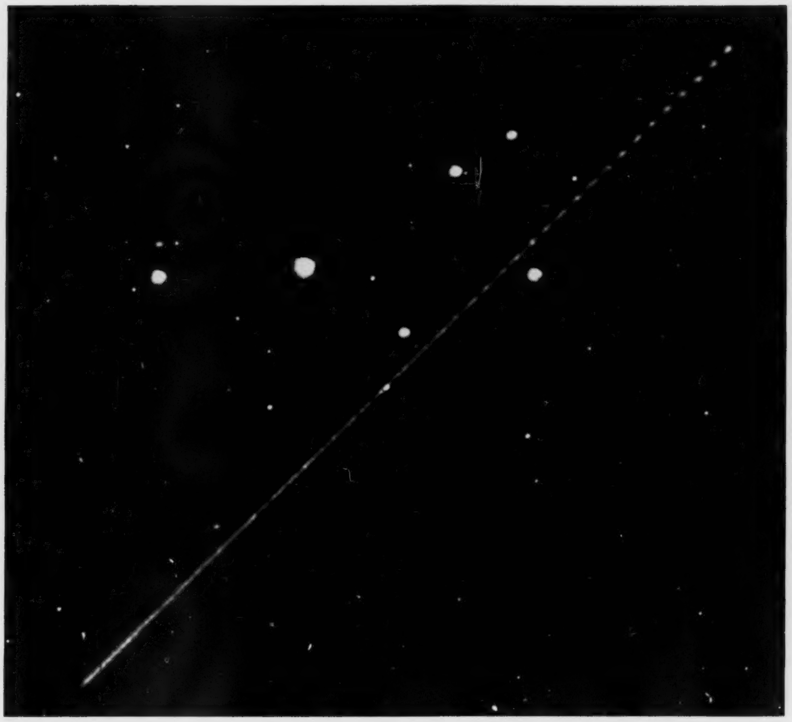
Another problem concerns the electrostatic fields at heights of 600 miles and more. Does the earth with its atmosphere form a charged or a neutral electrical system? It is possible that Sputnik may contain equipment for direct measurements of the ionic concentrations at various heights between its apogee and perigee distances.

The visual satellite-tracking program



A Soviet wirephoto shows the 23-inch man-made moon on a support, with the antenna rods that were folded against the rocket body.





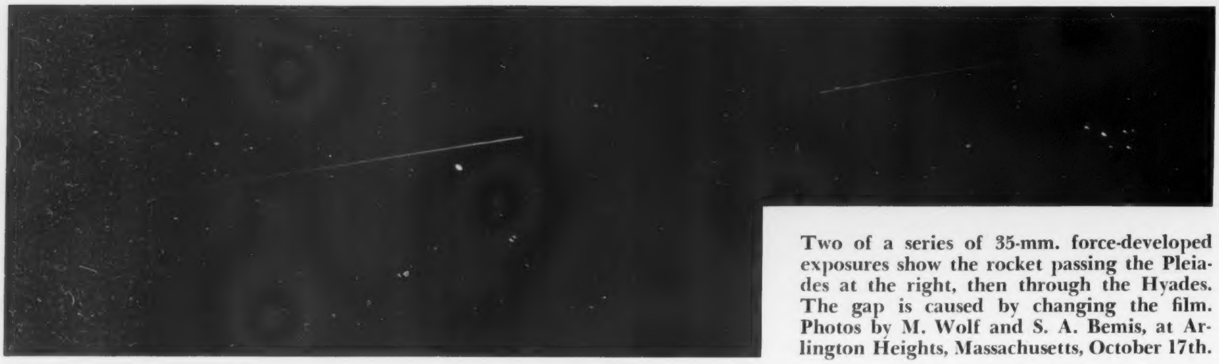
Above: At Louisiana State University, Baton Rouge, the rocket passed across the Pleiades cluster on October 19th, when Ray Grenchik, Jonas Holdeman, and Kenneth M. Yoss took this picture at 5:13 a.m. CST. Removing the cap of the 4-inch f/5 lens caused strong vibrations at the beginning of the three-second exposure, in the upper right.

Left: Zooming high over Hanscom Field, Bedford, Massachusetts, the rocket made a short trail in a two-second exposure at 5:09 a.m. EST, October 14th. Photograph by Geophysics Research Directorate, Air Force Cambridge Research Center, where radio observations were also being made.

Below: In Moscow, children in the radio room of the 59th School listen to signals from the tiny sphere several hundred miles above them.

in the Soviet Union is closely patterned after the American MOONWATCH organization, according to information released at the recent meeting of the International Astronautical Federation at Barcelona, Spain. The co-ordinator of the Russian observing teams is Mrs. A. G. Masevich, a well-known Moscow astrophysicist. She had visited the United States in June and at MOONWATCH headquarters obtained a sample observing telescope and information on our observing methods.

At the time of the Sputnik I launching, there were in the U. S. S. R. 66 satellite observing stations, about 30 of them connected with colleges and three with observatories. The 25 or 30 members of each team are volunteer observers. The arrangement of the observing posts is like that at most MOONWATCH stations in the United States, but no meridian mast is used. The Russian telescopes have a plane mirror in front of the objective,



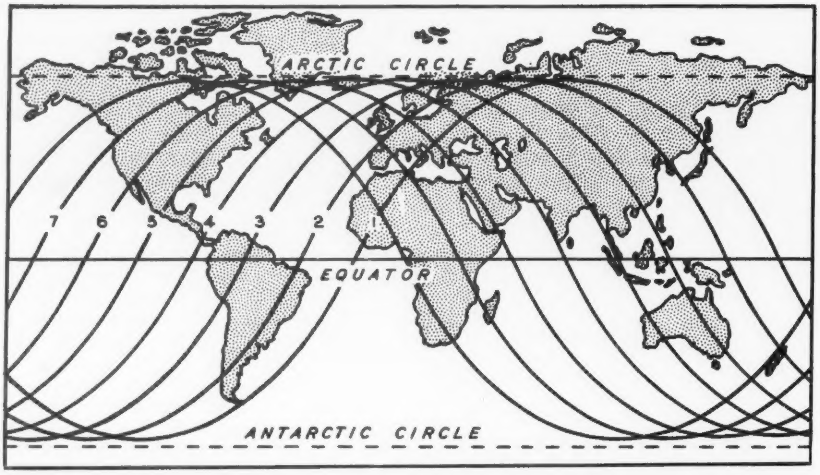
Two of a series of 35-mm. force-developed exposures show the rocket passing the Pleiades at the right, then through the Hyades. The gap is caused by changing the film. Photos by M. Wolf and S. A. Bemis, at Arlington Heights, Massachusetts, October 17th.

but they are bulkier and much less portable. The first Soviet nationwide visual observing alerts were held on September 24th and October 1st, some four months after the first American test alerts.

Radio observations of Sputnik were carried on in Russia at 26 special radio clubs that assist the armed forces there, each one lavishly supplied with radio equipment. In addition, thousands of radio amateurs in the U. S. S. R. recorded the messages from the satellite.

For photographic observing in the United States, the first Smithsonian satellite-tracking camera was set up for testing in South Pasadena, California, the only instrument of such power designed specifically for satellite observing. This program calls for a dozen instruments of the same kind to be set up at stations widely spaced over the earth.

As the accompanying chart shows, the trajectory of the satellite carries it over practically all of the earth except the regions within the Arctic and Antarctic Circles. Owing to the earth's rotation, the angle of the trajectory to the equator differs from the 65-degree inclination of the plane of the orbit. When the satellite crosses into the Northern Hemisphere, the trajectory passes the equator at an angle of $71\frac{1}{2}$ degrees in a northeasterly direction. Then it gradually turns to the east and on reaching latitude 65° north begins to move southward, crossing the equator in a southeasterly direction at an angle of 59 degrees. In the Southern Hemisphere a latitude of 65° south is reached.



This diagram shows consecutive revolutions of the first satellite, beginning with a passage over Moscow. All parts of the earth, except the polar regions, are covered by the moonlet's flight.

In Texas, on the roof of the Ft. Worth Children's Museum, there are 11 MOONWATCH telescope tandems, each manned by a child-parent team. Both observers cover the same sky area, and there are relief teams for children and adults alike.

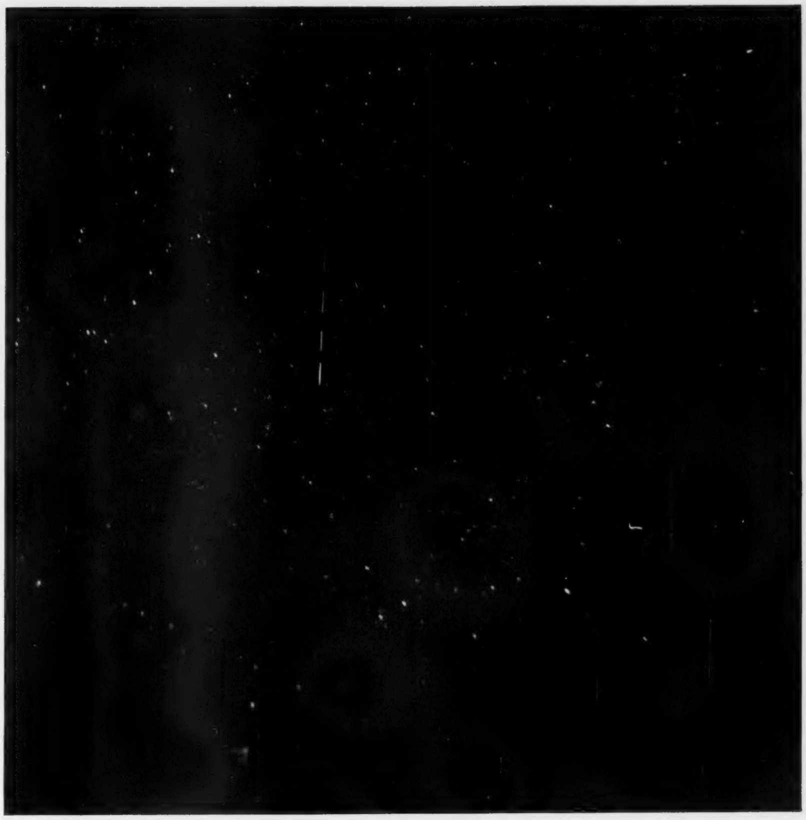
Since the time between the jettisoning of the nose cone and the detachment of the satellite from the third-stage rocket was not very great, the rocket and the cone were comparatively near the satellite for some time. They circled the earth along orbits very close to that of Sputnik. Then, owing to the difference in revolution periods arising from their relative speeds at the time of detachment, and from the varying degrees of atmospheric resistance to their different shapes, the three objects moved apart. Computations at the Smithsonian Institution Astrophysical Observatory showed that on October 29th, at 3:24 p.m. Eastern standard time, the rocket case lapped the satellite sphere while they were passing above the South Pacific Ocean.

Dr. Paul Herget, director of the Cincinnati Observatory and one of the astronomers who has been calculating the orbit of the satellite at the Vanguard Computing Center in Washington, calls attention to a misconception that was italicized on page 11 of the November issue. He writes:

"The empty rocket shell is, in a manner of speaking, *always* ahead of the actual satellite, even if there is no drag. The state of affairs is baffling to the uninitiated, and arises from the fact that after burnout the two are 'sprung' apart. Perhaps the following illustration will help clarify the matter:

"Suppose that the rocket and satellite are initially moving together in a circular orbit, hence with the same velocity. Now, if the two bodies are sprung apart, the satellite of necessity attains a slightly larger velocity than it had before, and it will now be moving in an orbit that is larger than the initial circle.

"Also, the period of the satellite is increased while that of the rocket is decreased, and therefore the rocket will complete its first revolution around the earth before the satellite does, simply because it is in a smaller orbit of shorter period. In succeeding revolutions it continues to pull ahead of the satellite, even if there is no drag. The earliest observations of the two bodies showed that the satellite had been 'sprung' with a velocity of 2.1 feet per second relative to the rocket."



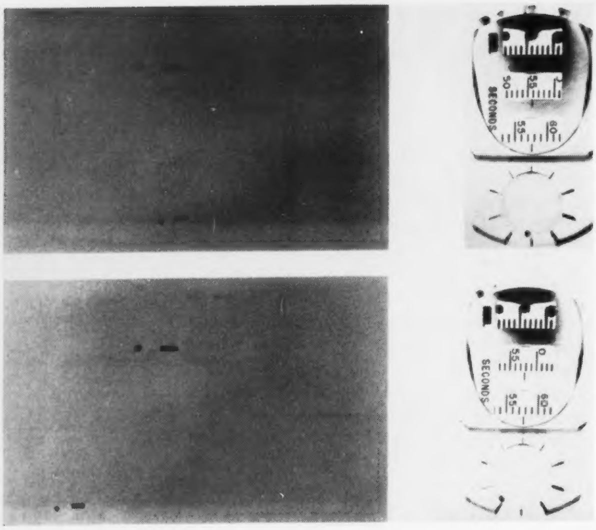
Sputnik's rocket was timed by John Gregory on October 16th as it rose to the northwest over the rooftops of Springdale, Connecticut. A rotating shutter chopped the trail into six-second intervals, the first beginning at 4:58:24 EST, about five minutes before Mr. Gregory took the cover picture of the rocket descending in the southeast. The film used was Royal-X Pan.

Orbit calculations at the Vanguard Computing Center, using an IBM 704 electronic digital computer, have been carried on by Dr. Herget, G. M. Clemence, director of the U. S. Nautical Almanac Office, and R. L. Duncombe. When Sputnik was transmitting radio signals, its orbit could be computed from radio

Compare this picture, taken at 4:56 m. EST, October 17th, with the one the top of the facing page. M. Sgt. Lester L. Leonard took this photograph at the Boston Army Base, about 11 miles southeast of Arlington Heights. Thus, the effect of parallax is evident where the track passes Aldebaran, in Taurus. A new-type army combat camera was used, with an Ektar 8-inch lens, working at f/4 on Tri-X film. U. S. Army photograph.

Near Leningrad, these satellite telescopes are being manned by astronomers of the Poulkovo Observatory, which is seen in the background. Photograph from the U. S. S. R. Embassy, Washington, D. C.

At Boston University, F. Dow Smith took this time exposure at 5:11 a.m. EST, October 14th, with an 8-inch f/5 lens. The shutter cycle broke the rocket's trail at 1.2-second intervals that allowed precise positions to be measured.



A clock records the time to 1/1,000 second in these precision photographs with the first Smithsonian satellite-tracking camera, set up for testing at South Pasadena, California. Taken October 17th at 5:06 a.m. PST, each frame shows a long and short trail of the bright star Beta Aurigae at the top, and of the rocket at the bottom.

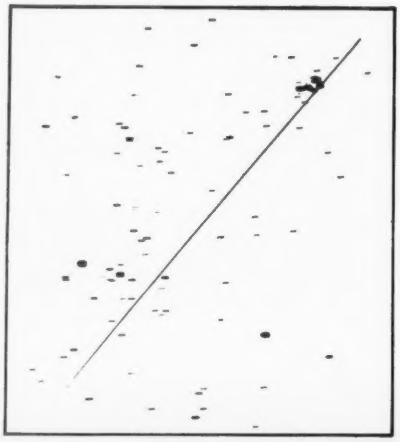
observations from many parts of the world.

Meanwhile, at Cambridge, Massachusetts, Smithsonian astronomers have been analyzing optical observations with the aid of an IBM 704 at Massachusetts Institute of Technology. These observations have so far been almost entirely of the rocket, which is bright enough to be easily seen without optical aid. To derive the orbital elements in Harvard *Announcement Card* 1375, reproduced on page 67, the IBM 704 required 21 seconds, making 40,000 calculations per second. But programming the operations for the computer is a lengthy problem, work on its satellite program having been begun last February.

As the earth's upper atmosphere begins to be populated with man-made astronomical objects, there may eventually be many satellites in simultaneous existence. Some simple and generally understood nomenclature for these bodies is therefore urgently needed, to avoid the confusion already evident in the case of Sputnik and its companions.

One proposal, made by Harvard astronomer Fred L. Whipple, is coming into widespread use. Each satellite is to be named by the year of its launching, followed by a lower-case letter of the Greek alphabet to indicate the order during the year. If more than one object is observable from a single launching, an Arabic number will be added to indicate the decreasing order of brightness among the components of that launching.

According to this scheme, the bright and easily seen third stage of the October 4th rocket will be called 1957α1, while the faint 23-inch sphere becomes 1957α2. It is the latter object to which the label Sputnik I properly applies.



Left: R. S. Powell, Schenectady, New York, recorded the trail of the rocket in a 10-second dawn exposure on October 17th. It streaked upward in the northwest past the five bright stars of Cassiopeia, which is in the right part of the picture.

Right: In this reverse print of a picture by Leonard Johnson at Neodesha, Kansas, with a press camera, the rocket's trail leads from the tightly clustered Pleiades, in the upper right, southeastward through the Hyades. The time was 5:12 a.m. CST, October 19th. R. W. Crowder, who contributed the picture, timed the observations with WWV signals.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 98th meeting of the American Astronomical Society at Urbana, Illinois, in August. Complete abstracts will appear in the Astronomical Journal.

Atmospheres of B Stars

At the University of Michigan Observatory, in work supported by a National Science Foundation grant, L. H. Aller and Jun Jugaku have studied the atmospheres of the hot blue stars of spectral type *B*.

These are relatively young stars, with their ages measured in terms of a few million years. Presumably they were formed from the interstellar medium in the spiral arms of our galaxy. Since they consume their nuclear fuel (hydrogen) hundreds of times faster than does the sun, their lifetimes must be rather short.

According to present ideas of stellar evolution, the heavier elements are produced in the dense, hot cores of massive stars that subsequently eject these materials into interstellar space. This interstellar material is again collected into stars and the same process is repeated in the more massive objects.

The sun, however, is an old, slowly evolving star formed about 5,000 million years ago; it must have a smaller fraction of heavier elements than a star made only recently from the interstellar medium. Hence, a comparison of the composition of the sun with that of a young *B* star should reveal the extent to which the process of element building has proceeded in the last four or five billion years. The Michigan astronomers have sought to establish the relative abundances of hydrogen, helium, carbon, nitrogen, oxygen, neon, magnesium, aluminum, sulphur, phosphorus, silicon, and other important elements in the *B* stars.

But the quantitative analysis of *B*-star spectra turns out to be very difficult. We must deduce the distribution of temperature and density with depth in the star. We must also know certain atomic constants, called transition probabilities and damping constants, concerned with the probability that an atom of a given element will absorb a particular spectral line. Unfortunately, these constants are not known for many strategic elements, so they have to be estimated by approximate physical theories. These inaccuracies, plus the uncertainties connected with the structure of the star's atmosphere, limit the accuracy of the final results.

Particularly difficult is the establishment of the ratio of hydrogen to helium; here much more work needs to be done in the laboratory before the situation can be improved. As for the other elements, such as silicon, oxygen, and the like, their abundances with respect to hydrogen do not seem to be substantially greater in the young stars than in the sun.

The one conclusion that may be drawn is that the rate of element building, and presumably of star formation as well, must have proceeded at a much slower rate since the sun was formed than it did in the earliest stages of our galaxy, when the skies must have been brilliant with many more intrinsically bright stars than adorn them at the present time.

Radio Sources Outside Our Galaxy

An important branch of radio astronomy is concerned with distant discrete sources of energy. These strongly localized centers of emission, formerly called radio stars, are readily distinguishable from the general radio noise of our Milky Way galaxy.

A small number of the known discrete sources can be identified with visible objects, such as old galactic supernovae. The remaining sources, most of them probably lying outside our system, formed the subject of a stimulating symposium at Urbana, four leading investigators from three continents taking part.

R. Minkowski, of Mount Wilson and Palomar Observatories, was concerned with the problem of the optical identification of discrete sources. He first pointed out that the sources are regarded as extragalactic because their distribution over the sky is nearly uniform, like that of galaxies, rather than concentrated toward the Milky Way. The only alternative, which he stated was improbable, is that the discrete sources are stars of extremely low luminosity within a few parsecs of the sun.

The first step toward an identification is to find satisfactory positional agreement between a radio source and an optical object that is obviously peculiar or bright enough to make the coincidence potentially significant. Present radio surveys, as a rule, can fix a source only somewhere within a sky area of about 100 square minutes of arc. According to E. P. Hubble's census of galaxies, an area of this size will, on the average, contain a single galaxy of the 17th magnitude and a large number of fainter ones. Hence, the occurrence near a source position of a galaxy fainter than the 17th magnitude cannot be considered significant, unless the galaxy shows some noteworthy peculiarity, such as being a member of a colliding pair.

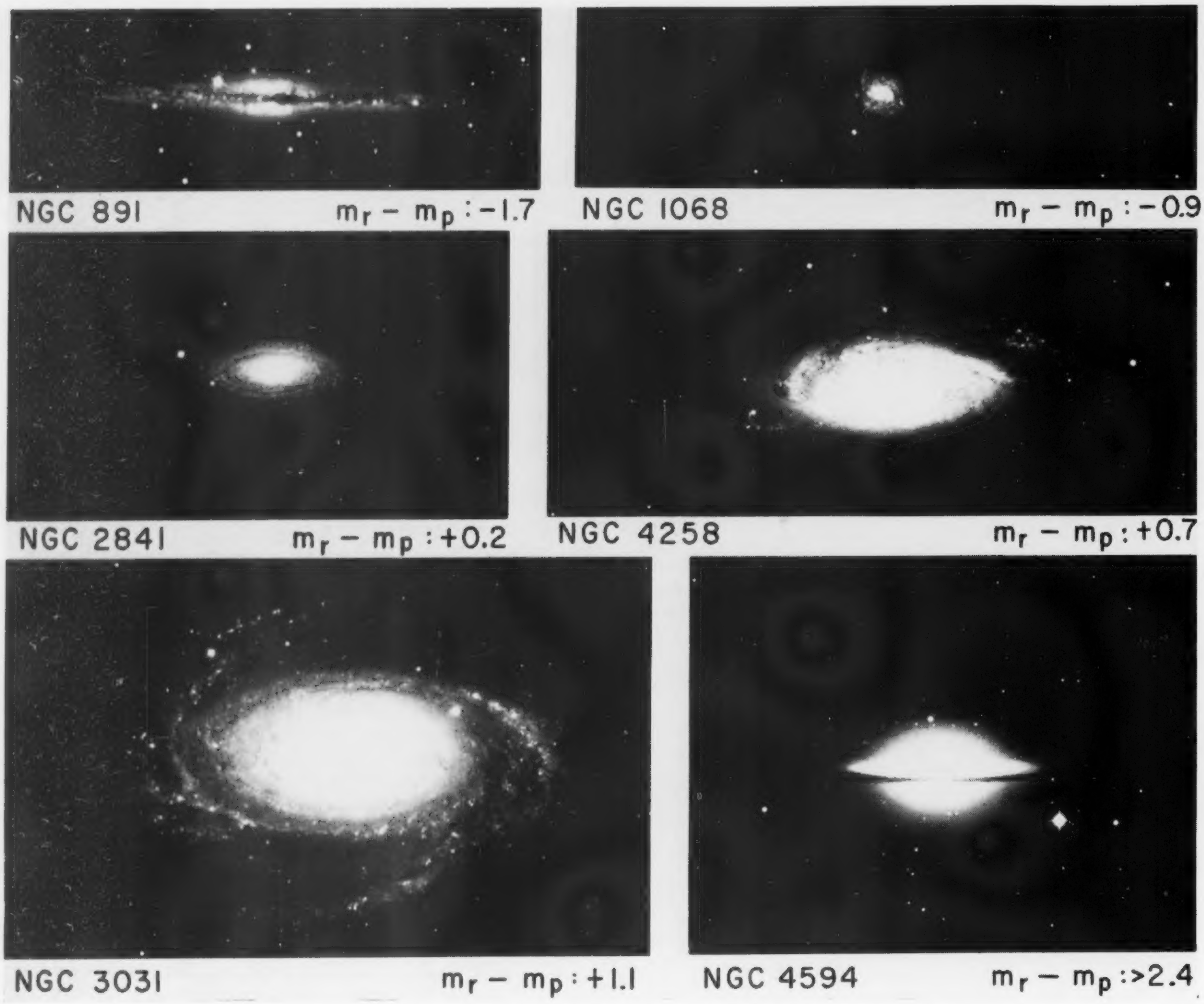
Positional coincidence is usually not sufficient evidence for an identification. The size of the source, its optical appearance, and the spectrum of the object may furnish additional information. As observational techniques are developed, the continuous radio spectrum of an object and the red shift of its 21-cm. neutral hydrogen line may become of great importance.

From the few trustworthy identifications that have been made, it appears that the ratio of radio to optical brightness may differ very greatly from galaxy to galaxy. Perhaps 10 to 20 per cent of all sources are disproportionately strong, radiowise, compared to their optical brightness. An example is Cygnus A, for which the radio magnitude used by Dr. Minkowski differs by 14 from its optical magnitude, a scale difference of 400,000 times. The radio magnitude limit of present surveys is about 10, so a source like Cygnus A at that limit would be optically beyond the power of even the 200-inch telescope.

Even somewhat weaker emitters, such as Hydra A, where the optical-radio difference is 12 magnitudes, would be mostly very faint optically. With the present low accuracy of radio pointing, the great majority of sources cannot be identified if, for the bulk of them, the optical and radio brightness differ by more than eight magnitudes, or 600 times.

Thus, only a very small per cent of radio sources can be associated even

Speakers at the symposium on radio astronomy at Urbana were, left to right: A. Hewish, Cavendish Laboratory; G. C. McVittie, Illinois Observatory; R. Minkowski, Mount Wilson and Palomar Observatories; and J. L. Pawsey, Radiophysics Laboratory, Sydney.



Six galaxies for which the radio and photographic magnitudes are known. They are arranged, from top to bottom, in order of decreasing radio intensity compared with optical brightness. Mount Wilson and Palomar Observatories photograph.

tentatively with specific galaxies, Dr. Minkowski has found from a systematic study of a sky area containing 330 known discrete sources. This small percentage should consist mostly of relatively weak emitters, such as NGC 1275, a colliding pair of galaxies for which the optical-radio magnitude difference is six.

A double or multiple galaxy may sometimes be a radio source, even when no sign of interaction among its components is visible. Colliding galaxies are so rare, except in clusters, as to account for very few sources; over the entire sky only about 10 such collisions are in progress for galaxies down to the 18th magnitude.

Bright galaxies are, in general, poor radio emitters, Dr. Minkowski pointed out. No elliptical-type system has been observed as a source, and the 20 normal systems regarded as sources are primarily spirals of types Sb and Sc. The six pictures shown here are labeled with the radio-photographic magnitude differences. The radio emission of normal galaxies of type Sb seems to be stronger, compared to the optical brightness, for systems like NGC 891, in which the spherical mass is relatively unimportant, than for systems like NGC 4594, in which the spherical mass predominates. This strongly suggests that radio emission from normal galaxies is not connected with the stars of Population II, but with the spiral structure.

Two of the symposium speakers discussed the discordant results of recent surveys of discrete radio sources carried out in England and Australia. From Cavendish Laboratory, Cambridge, A. Hewish brought information on the most recent work of this kind there, while J. L. Pawsey did the same for the Radiophysics Laboratory at Sydney.

As reported in *Sky and Telescope* for June, 1956, page 344, at Cambridge most of the sky has been mapped on a wave length of 3.7 meters, and a catalogue of 1,936 sources was published. On the basis of this survey, M. Ryle and P. A. G. Scheuer announced that faint sources were unexpectedly abundant; there were more of them than could be explained by a static Euclidean universe. Apparently, this result indicated a change in the properties of the universe at extreme distances.

In 1957, B. Y. Mills and his colleagues, using the Mills Cross antenna pictured on page 24 in November, 1955, made a similar survey. Except for the stronger sources, the two surveys disagree with respect to individual sources and in their intensity statistics. Besides random errors in measuring the flux density of sources, work with interferometer-type antennas is troubled with ghost images of strong sources located in other parts of the sky, because of the side lobes in the antenna's reception pattern. And serious errors due to confusion of sources may occur if we attempt to pick out individual sources that are more closely distributed than about one to 10 or 20 beam areas. In this respect the Sydney survey seems to have been far more reliable than the first one at Cambridge. The Sydney results give at most only a very slight ex-

cess of the faintest discrete sources.

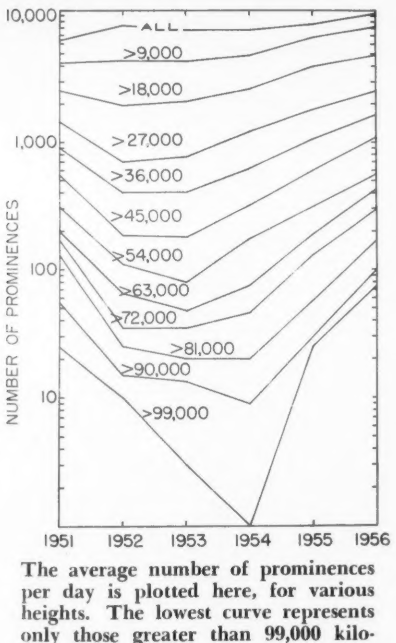
Mr. Hewish stated that the errors due to confusion of sources in the first program at Cambridge were considerably worse than had been realized, and that many of the sources in the original catalogue should now be called unreliable. But a further survey has been made with the Cambridge instrument at a wave length of 1.9 meters, improving the angular resolution about four times over that at 3.7 meters. For a sample area eight hours long in right ascension and extending 10 degrees on either side of the celestial equator, there is now good agreement with Mills' results for about one third of the sources, but the remainder are either of doubtful correspondence or are not compatible. Some sources observed by Mills do not appear on the Cambridge records at all! Furthermore, the new survey still suggests an excess of faint sources, though somewhat less than that originally proposed by Ryle and Scheuer.

Dr. Pawsey pointed out that such discrepancies may best be resolved by repetition of the observations with a third instrument, known not to be subject to the errors characteristic of the interferometer type. Especially suitable for this work would be the 250-foot paraboloid at Jodrell Bank Experimental Station, England, pictured in *Sky and Telescope* for September, 1957, page 516. Such an instrument has adequate resolution for this work at any wave length less than half a meter.

The fourth symposium speaker was George C. McVittie, University of Illinois Observatory, who discussed the large-scale properties of the universe as indicated by counts of extragalactic radio sources. In a sense, his problem was analogous to the earlier efforts of cosmologists to investigate the space density of matter and the curvature of space from optical counts of faint and distant galaxies.

Using mathematical models of the universe computed with certain simplifying assumptions, Dr. McVittie has devised equations connecting the radio counts with the properties of these idealized universes. If the average radio source is as weak as NGC 1275, then the Sydney survey referred to above would be compatible with a uniform model universe. But if the average source has the high intensity of Cygnus A, then the Sydney catalogue would require the sources to be much more remote, undergoing large progressive changes in their radiating strengths.

Dr. McVittie applied a similar analysis to the Cambridge catalogue, but this set of data could not be fitted satisfactorily to his particular set of equations. He pointed out that before safe cosmological conclusions can be drawn from radio-source statistics, the serious discrepancies between the catalogues of different observatories must be corrected, and it will be necessary also to know the individual distances of a representative number of extragalactic sources.



The average number of prominences per day is plotted here, for various heights. The lowest curve represents only those greater than 99,000 kilometers high, the next all prominences higher than 90,000 kilometers, and so on at 9,000-kilometer intervals.

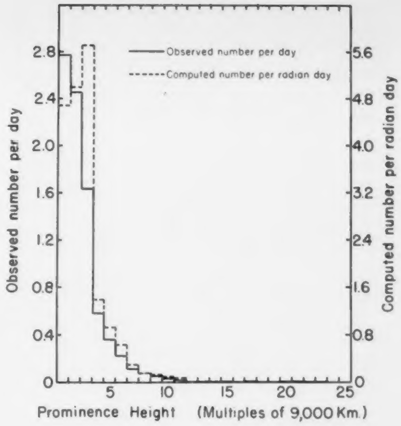
Heights of Solar Prominences

At the High Altitude Observatory, Boulder, Colorado, Donald E. Billings and Carolyn Kober have measured the heights of distinguishable prominences on the sun for the years 1951 to 1956, using all the records in the Climax station and Sacramento Peak Observatory photographic surveys during that six-year period.

They find that the occurrence of prominences extending to considerable heights above the chromosphere is strongly dependent on the solar cycle. For instance, in the accompanying chart, the counted daily number of prominences higher than 99,000 kilometers dropped to a deep minimum in 1954, but since then has risen rapidly, reaching more than 70 in 1956. The solar-cycle effect becomes increasingly noticeable with heights of 27,000 kilometers and greater.

It is just at about that level that the Colorado astronomers find another very important effect. For all years, independent of the level of solar activity, the number of prominences attaining a given height decreases much faster between 27,000 and 36,000 kilometers than in any other height interval. In other words, there appears to be a unique layer in the solar corona, at about 30,000 kilometers above the chromosphere, above which the probability of prominence occurrence drops sharply.

This is illustrated in the second chart, where the solid line shows observed heights as projected upon the plane of the solar disk. The dashed line gives computed results on the assumption that each prominence is a spikelike object, with negligible line-of-sight extent. Were the prominences all long hedgerow-type structures completely encircling the sun (*Sky and Telescope*, August, 1957, page 464), the actual and observed distributions of heights would be the same. Since prominences are on the average intermediate in structure between these two extremes, the actual distribution should lie between the solid and the dotted curves.



The distribution of prominence heights during the years 1951-1956, inclusive. Note the abrupt drop in both observed and computed curves in the height interval 27,000 to 36,000 kilometers. These charts are from the High Altitude Observatory.

Catalogue of Magnetic Stars

There are now 86 stars definitely known to have magnetic fields, according to Horace W. Babcock, Mount Wilson and Palomar Observatories, who reported the results of an 11-year program with the coude spectrographs of the 200- and 100-inch telescopes.

Such stars can be recognized by the Zeeman effect—the splitting into polarized components of the spectral lines originating in a strong magnetic field. The separation of the components is larger the stronger the magnetic field, but does not exceed a few tenths of an angstrom unit for any star known. Because of the minuteness of this effect, the test can be applied only to stars with narrow spectral lines, unwidened by stellar rotation.

Of the 86 definite magnetic stars, 66 are of spectral type *A* with sharp lines. The remainder consists of seven metallic-line stars, one subdwarf, one cluster-type variable, two *S*-type stars, and three giant stars with spectra of class *M*. It thus seems that stars in any part of the Hertzsprung-Russell diagram may have magnetic fields.

Dr. Babcock suggests that a stellar magnetic field is generated as a consequence

(*Continued on page 73*)

Cleveland's Large Schmidt Telescope Moved

VICTOR M. BLANCO
Warner and Swasey Observatory

At its new location near Chardon, Ohio, the 24-36-inch Schmidt telescope of the Warner and Swasey Observatory is sheltered by a dome with a 26-foot inner diameter. Photograph by Rebman Photo Service.

ON SEPTEMBER 7th, in an outdoor ceremony near Chardon, Ohio, the Nassau Astronomical Station was dedicated. It is named for Dr. Jason J. Nassau, head of the astronomy department at Case Institute of Technology and director of the Warner and Swasey Observatory.

Dr. Nassau's three decades at Case have made its astronomical department one of the best known in the country. He and his students have made extensive contributions to stellar spectroscopy, fundamental photometry, statistical astronomy, and the study of globular clusters and variable stars.

In selecting this new location for the 24-36-inch Burrell Schmidt-type telescope, Case astronomers considered the transparency and darkness of the night sky, avoidance of growth patterns of the nearer cities, and ease of access from Warner and Swasey Observatory headquarters in East Cleveland. At the new site, exposures with the Schmidt can be three times longer than was possible in the East Cleveland location in recent years. Furthermore, low-level cloud patterns associated with Lake Erie may be avoided.

The dedication took place exactly 14 months after ground breaking at the 180-acre plot, which is located 30 miles east of the Warner and Swasey Observatory, at an elevation of 1,250 feet above sea level. The new building contains all the necessary observing facilities. On the second-floor level are the observing floor, darkrooms, a small room for the electronic frequency controls of the telescope, and a workroom for maintenance tools, a microscope, charts and catalogues. Living facilities on the first floor enable observers to stay at the station for several days at a time.

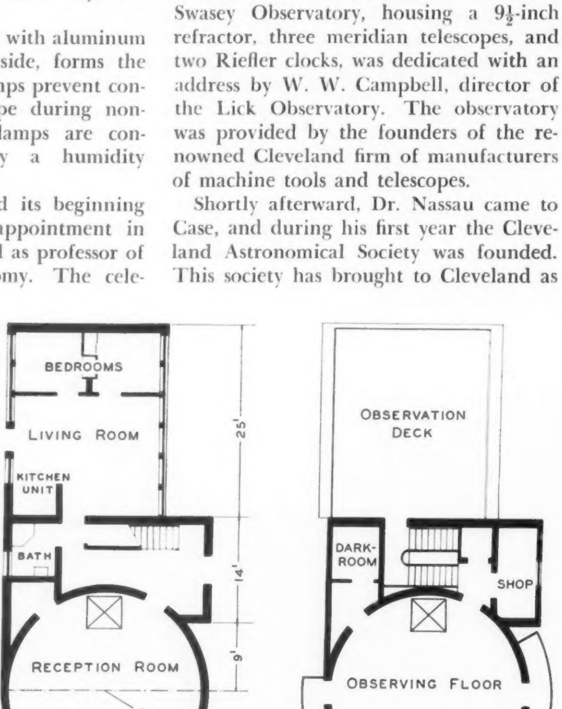
Structural steel, covered with aluminum and insulated on the inside, forms the dome. Within it, heat lamps prevent condensation in the telescope during nonobserving hours; these lamps are controlled automatically by a humidity sensor.

Astronomy at Case had its beginning with the new college's appointment in 1882 of John N. Stockwell as professor of mathematics and astronomy. The celebrated Benjamin A. Gould was invited to visit Cleveland, where he approved of Stockwell's policy in which teaching and research were to go hand in hand. This emphasis on scientific research was shown in the college's first year, when out of its income of $35,000 the sum of $10,000 was made available to a young professor of physics, A. A. Michelson, whose work at Case culminated in the world-famous Michelson-Morley experiment.

Charles S. Howe succeeded Stockwell and in 1900 established the first Case observatory, a temporary structure housing two meridian telescopes and a 9-inch almucantar. In 1920 the Warner and Swasey Observatory, housing a 9½-inch refractor, three meridian telescopes, and two Riefler clocks, was dedicated with an address by W. W. Campbell, director of the Lick Observatory. The observatory was provided by the founders of the renowned Cleveland firm of manufacturers of machine tools and telescopes.

Shortly afterward, Dr. Nassau came to Case, and during his first year the Cleveland Astronomical Society was founded. This society has brought to Cleveland as

These plans of the Nassau Astronomical Station show the arrangement of the ground-floor living quarters for observers. The large reception chamber can also serve as a workroom. The outdoor observation deck is at a lower level than the telescope's observing floor, as seen at the right in the photograph at the top of this page.



GROUND FLOOR PLAN

This picture was taken last spring, as the polar axle of the Burrell telescope was being readied for shipment to its new location. With the workmen are the author (straddling the polar axle) and H. Cook (wearing hat). Seventeen years ago, Mr. Cook directed the original installation of this telescope, and he has also supervised other installations, including that of the 82-inch reflector of the McDonald Observatory in Texas.

lecturers many outstanding scientists, and has established an annual fellowship for young astronomers to do research at Case. In 1940, the 24-36-inch telescope and its dome, as well as exhibit and lecture halls, library and offices, were added to the observatory, the dedication address being given by Otto Struve, then of Yerkes Observatory.

Being ideally suited for the study of large areas of the sky, the new telescope was put to work on problems of Milky Way structure. A search for stars of spectral types *O* and early *B*, in which Dr. Nassau collaborated with W. W. Morgan, of Yerkes Observatory, proved to be very timely. These were the stars with which Dr. Morgan was later able to trace the spiral structure of our galaxy. An extensive survey of galactic red stars was initiated by Dr. Nassau with the aid of G. B. van Albada. For this purpose, spectral classification criteria were developed for infrared-sensitive plates. These surveys, now completed, have given invaluable information about the space distribution of the disk components of the galaxy.

At the new location, lack of excessive sky fog makes it possible to take photographs closer to the horizon, including the galactic-center regions that are so important in Milky Way research. Observations made at the Nassau station have already shown the existence of recently formed *M*-type subgiants in the extremely young cluster NGC 6530. Such work was not possible at the original location of the telescope.

Plans for research at the Nassau station include detailed spectroscopic surveys in selected galactic regions. Tests show the feasibility of spectral classifications with the 4-degree objective prism of stars as faint as magnitude 13.5, in the photographic regions of the spectrum. With the 2-degree prism, a limit fainter by half a magnitude may be possible. The redder stars may be classified by infrared techniques to a limiting photographic magnitude of 19.5.

Regularly scheduled public nights at the observatory have made Clevelanders astronomy conscious through the years. This educational program has been recognized by the Cleveland Foundation and the Warner and Swasey Co., who are supporting the erection of a new 36-inch Cassegrainian telescope in the place vacated by the Schmidt. The same piers are being used, and the installation is taking place as this article goes to press.

A gift of $100,000 from Miss Helen B. Warner, daughter of Worcester R. Warner, spearheaded the drive for funds to establish the Nassau station. A grant of $20,000 was made by the National Science Foundation, and the support of the Cleveland Astronomical Society helped the project materially.

QUESTIONS... FROM THE S+T MAILBAG

Q. How big is Betelgeuse compared to the sun?

A. The diameter of Betelgeuse, a pulsating red supergiant star, varies irregularly from 360 to 530 times that of the sun, according to the sixth edition of *Astronomy*, by R. H. Baker.

Q. Are Gamma Scorpii and Sigma Librae the same star?

A. Yes. Bayer originally assigned the former name about 350 years ago. The latter designation was preferred by B. A. Gould when he systematized the nomenclature of naked-eye southern stars around 1877.

Q. What is the meaning of the dates January 0 and December 32 that appear in tables in the *American Ephemeris and Nautical Almanac?*

A. These dates provide an overlap from one year to the next. January 0, 1957, is the equivalent of December 31, 1956, while December 32, 1957, is the same as January 1, 1958.

Q. What does it mean to say that an optical surface is corrected to $\frac{1}{8}$ wave?

A. It means that nowhere does the surface deviate from the desired shape or figure by more than a distance equal to $\frac{1}{8}$ the wave length of the light used to test it. For sodium light, of wave length 5893 angstroms, one wave length is 0.0000232 inch, so that $\frac{1}{8}$-wave correction amounts to an accuracy of about three millionths of an inch.

Q. What is the best material to use for illuminated crosshairs in eyepieces of short focal length?

A. Spider web, because it is very fine, yet has sufficient elasticity to remain stretched tightly even when extreme changes in humidity or temperature occur.

Q. Where do I look to see the Horsehead nebula?

A. The Horsehead nebula is a dark cloud located about 30 minutes of arc south of the star Zeta Orionis, but it is very difficult to see. This object is treated in Deep-Sky Wonders for this month, on page 84. W. E. S.

ANOTHER RUSSIAN SATELLITE

(*Continued from page 55*)

states, and on the 7th, many MOONWATCH stations from coast to coast secured accurately timed positions. Viewers generally called the fast-moving speck of light 1st magnitude or brighter, but with rapid fluctuations in brightness.

The abundance and quality of the early observations, both radio and visual, suggest that amateur satellite tracking has already become well established.

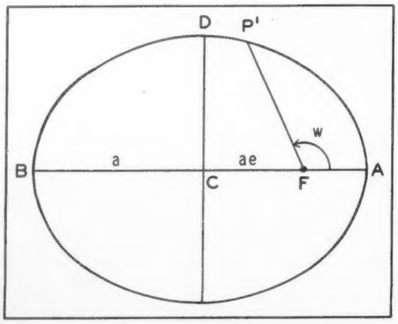
Celestial Mechanics of Artificial Satellites

THEODORE E. STERNE, *Smithsonian Astrophysical and Harvard College Observatories*

VAST NUMBERS of people have been following the careers of the new astronomical bodies launched into space on October 4, 1957. The motions of the faint satellite and its associated bright rocket have provided excellent illustrations of celestial mechanics, and have aroused a widening interest in that astronomical specialty.

Were Isaac Newton still alive today, he would appreciate this practical application of the conclusions he reached, nearly 300 years ago, concerning the precise dependence of the orbit of a projectile on its launching conditions. He would have welcomed the physical realization of some of the drawings in his *Principia Mathematica,* in one of which a satellite is launched from a cannon on a mountaintop. Doubtless his remarkable geometrical insight would have enabled him to make some very early predictions by ruler, compass, and pencil, without reliance on a digital electronic computer.

A basic concept of celestial mechanics is that the path of a lightweight body or satellite around a massive particle is a conic section with the massive particle at its focus, if the light body is attracted by a gravitational force varying as the inverse square of the distance and directed toward the massive particle.



The elliptical orbit of a particle P' around mass point F is the simplest model of an artificial satellite's motion.

Sir Isaac Newton (1643-1727), after the painting by E. Seeman. His researches foreshadowed many artificial satellite problems, such as the theory of rocket propulsion, and the mathematics of orbital motion, perturbations, and air resistance.

MOTION IN AN ELLIPTICAL ORBIT

Unless the launching velocity is too great, the orbit is an ellipse, such as that diagrammed here, with the *semimajor axis* BC denoted by a. The distance from the center, C, to the focus, F, is ae, where e, a number less than one for an ellipse, is called the *eccentricity* of the orbit. The length of the *semiminor axis,* CD, is then $a(1 - e^2)^{1/2}$. The end A of the major axis that is closer to the focus is called the *pericenter,* and the other end B is the *apocenter;* for an earth satellite we may use the more specific names *perigee* and *apogee.*

When the satellite is at any point, P', in its orbit, the angle AFP' is called the *true anomaly,* measured in the direction of motion and often denoted by w. As the satellite moves, the area AFP' (bounded by two straight lines and an elliptical arc) increases uniformly with the time—an illustration of Kepler's second law. The complete time, P, for one revolution is called the *period,* and $2\pi/P$ is the *mean motion,* n; it is the average angular motion, here expressed in radians, of the satellite during the unit of time.

Kepler's third law gives us a simple relation between the mean motion and the length of the semimajor axis of the orbit,

$$n^2 a^3 = mG. \qquad (1)$$

Here m is the mass of the massive particle and G is the constant of gravitation. If the particle has the earth's mass, if we express distance in units of the earth's equatorial radius (6,378,388 meters), and if time is put into units of 806.83 seconds,

then the numerical value of mG is unity.

The distance FP′, of the satellite from the center of the earth, is called the *radius vector, r.* It is related to w, a, and e by the equation,

$$r = a\,(1 - e^2)/(1 + e \cos w). \qquad (2)$$

If T is the time of the satellite's perigee passage and t is any other moment of time, the product $n(t - T)$ is called the *mean anomaly, M.* We may visualize it as an angle that is zero at perigee and increases uniformly at a rate of 360 degrees per orbital period.

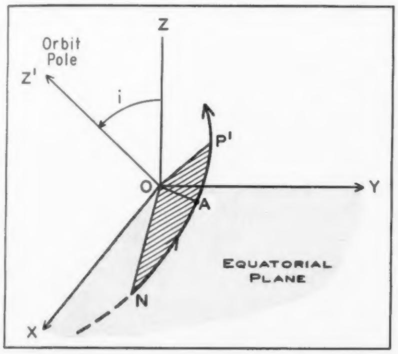
Forecasts of w and r can now be made for any instant t by means of the three formulae

$$M = E - e \sin E, \qquad (3)$$

$$\tan \tfrac{1}{2}w = (1 + e)^{1/2}(1 - e)^{-1/2} \tan \tfrac{1}{2}E, \qquad (4)$$

$$r = a\,(1 - e \cos E). \qquad (5)$$

The angle E, which is calculated as an intermediate step by Equation 3, known as Kepler's equation, is called the *eccentric anomaly.*



The arc NAP′ is a portion of the satellite's orbit, specified by the orbital elements defined in the text. The angle AOP′ is the true anomaly, corresponding to AFP′ in the diagram on the facing page.

The Orbit in Space

So far we have discussed only motion in the orbital plane. The next step is the description of the orientation of the orbit in space. For an earth satellite, the most convenient reference system is the set of rectangular axes in the above figure. The origin, O, is the center of the earth; XOY is the plane of the earth's equator; OX points to the vernal equinox and OZ toward the north celestial pole.

The satellite's orbit plane intersects the equatorial plane in the line of nodes, ON, and if N is where the satellite crosses the equator from south to north it is called the *ascending node.* The angle XON is the right ascension of the ascending node, and is denoted by Ω. Furthermore, if OZ′ is the pole of the orbit, in which the satellite's motion appears clockwise to someone sighting upward along OZ′, then the angle ZOZ′ is the *inclination, i,* of the orbit. Thus, the two angles, Ω and i, specify the orientation of the orbital plane in space.

The angle NOA, measured in the direction of the orbital motion, defines the position of the perigee, A, and is called ω. The *elements* of the satellite orbit are the numbers a, e, T, Ω, i, and ω, which describe it completely and unambiguously.

An early set of elements determined for the third-stage rocket of the first satellite is reproduced below, on Harvard *Announcement Card* 1375. Instead of T, the time of perigee passage, the true anomaly w is given for a time called the *instant of osculation,* whose significance will be discussed later. These elements are referred to the earth's equator, and thus are equatorial elements; for comets and asteroids the same symbols are used for the corresponding elements referred to the plane of the ecliptic. By convention, the elements were given on the card to more digits than observational accuracy demanded.

Predicting a Satellite's Position

The six elements are the same in number as the three co-ordinates of position and the three components of velocity required to specify the launching conditions completely. Newton showed how the elements could be inferred from the circumstances of launching.

Conversely, once the elements are known, the right ascension α, the declination δ, and the radius vector r of the satellite can be predicted for any time. We have already seen the equations for calculating w and r. Next, the right ascension and declination of the satellite are given by

$$\alpha = \Omega + \arctan\,[\cos i \tan\,(\omega + w)\,], \qquad (6)$$

$$\sin \delta = \sin i \sin\,(\omega + w). \qquad (7)$$

It should be emphasized that the two formulae just given apply only for an observer at the center of the earth, or to one directly beneath the satellite. But we wish to predict its position at any particular time for an observer at any selected place on the earth's surface. To do this we must find the x, y, z co-ordinates of the satellite and subtract them from the x', y', z' co-ordinates of the observer in the same equatorial system of co-ordinates. From the differences of these quantities, we can obtain the apparent right ascension and declination of the satellite.

The equatorial co-ordinates of the observer on the surface of a spherical earth of unit radius are

$$x' = \cos \phi \cos \theta, \qquad (8)$$

$$y' = \cos \phi \sin \theta, \qquad (9)$$

$$z' = \sin \phi, \qquad (10)$$

where ϕ is his latitude and θ is his local sidereal time.

The co-ordinates of the satellite are

$$x = r \cos \delta \cos \alpha, \qquad (11)$$

$$y = r \cos \delta \sin \alpha, \qquad (12)$$

$$z = r \sin \delta. \qquad (13)$$

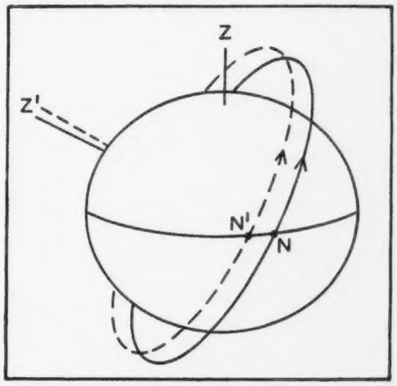
Then the apparent right ascension α', apparent declination δ', and the distance ρ of the satellite from the observer are computed from

$$x - x' = \rho \cos \delta' \cos \alpha', \qquad (14)$$

$$y - y' = \rho \cos \delta' \sin \alpha', \qquad (15)$$

$$z - z' = \rho \sin \delta'. \qquad (16)$$

These formulae do not allow for the earth's flattening or the observer's elevation above sea level, but these considerations merely make his co-ordinates slightly harder to calculate.



Our globe's spheroidal shape causes the satellite's orbital plane to turn slowly westward around the earth's axis. Thus, if one revolution about a nonrotating earth carries the satellite over the equator at N, on its next circuit it will cross at N′.

Perturbations of a Satellite

In our discussion of Equation 1, we assumed the massive particle at the center of attraction to have the earth's mass. The application of the formulae would not be changed by the earth's finite size, if the earth were spherical. In reality, however, the earth is not a sphere, and its equatorial radius exceeds its polar radius by about one part in 297. Consequently, the satellite is attracted to the earth by a net force that does not vary exactly as the inverse square of the distance from the earth's center, and the force is not directed exactly toward the center of the planet.

Therefore, it is only as a first approximation that the satellite is attracted as if our planet were replaced by a particle at its center with the same mass as the earth. For an improved, second approximation,

HARVARD COLLEGE OBSERVATORY

ANNOUNCEMENT CARD 1375

Satellite 1957α1. — Mr. Jack W. Slowey, Dr. Don A. Lautman, and Dr. Richard E. McCrosky of the Astrophysical Observatory of the Smithsonian Institution in Cambridge, Massachusetts, have obtained the following equatorial elements and perturbations for Satellite 1957α1:

a = 1.0890751 Earth

e = 0.0510696

i = 64°.26012

Argument Perigee = 61°.77894

Ω = 327°.33288

True Anomaly 266°.40725

Instant Osculation 1957 October 9.40466

The period appears to be shortening appreciably.

October 15, 1957 — Fred L. Whipple

The plane of the satellite orbit remains fixed in space (except for the effects of perturbations) while the earth turns on its axis within the orbit. These diagrams, based on releases from Moscow, show every third circuit of the first artificial satellite, over Russia, western Africa, United States, the eastern Pacific Ocean, and China.

we must allow for the attraction by the extra matter near the earth's equator and for the missing matter near the poles. Qualitatively speaking, the extra material attracts the satellite toward the equator, trying to rotate the orbit in the sense of decreasing the inclination about the line of nodes.

As with a gyroscope, however, the resultant effect is not to decrease the inclination, but to cause the axis of the orbit to revolve slowly about the earth's polar axis. In consequence, the right ascension of the node, Ω, gradually decreases. See the diagram on page 67, where during the course of one revolution of the satellite the node has shifted from N westward to N′.

Another effect of the earth's oblateness is to cause the perigee point to move along the orbit, so that ω is not constant. Consequently, the satellite has three different periods instead of one, yet none of these periods corresponds to what would be predicted from the value of a given by Equation 1.

1. Radial or *anomalistic* period, from one perigee passage to the next, 95.98492 minutes for the orbital elements cited above.

2. *Nodical* period, between successive passages of the satellite through the ascending node, 95.98863 minutes.

3. *Sidereal period,* of a complete revolution in right ascension, 96.04659 minutes.

Astronomers have in general two ways of studying the effects of disturbing forces on planet and satellite motions: special and absolute perturbations. In special perturbations, the exact equations of motion are integrated step by step by numerical methods, perhaps with large electronic digital computing machines that make the work much less tedious. For an artificial satellite, rapid calculation is necessary to keep up with the changing characteristics of the orbit.

Without disturbing forces, the orbital elements would be true constants, but when such forces are acting the elements vary with time. If, at a moment to be called the instant of osculation, all disturbing forces were removed, the satellite would travel in an elliptical orbit described by *osculating elements.* The elements of Harvard *Announcement Card* 1375 are of this sort.

In reality, the continued action of the disturbing forces causes the osculating elements to fail to represent the actual motion, but the theory of absolute perturbations allows the calculation of the changes of the elements with time. Thus, the position of the satellite can be computed by the usual formulae for a later time, using the changed values of the elements.

Some of these changes in the elements are periodic, others gradual. For the third-stage rocket of the first satellite, the predicted change in Ω is -3.25 degrees per day, calculated on the assumption that the earth's flattening is 1/297. A discrepancy between the observed and predicted behavior would mean that this value for the flattening could be improved. There is no convincing evidence of this yet.

Air resistance or *drag* can have marked effects on the motion of a satellite near the earth's surface, as observations of the first rocket show. Paradoxically, air resistance speeds up a satellite, by forcing it to fall into a smaller orbit, where the decreased value of a requires the period to be shorter. Thus, the nodical period of the Soviet rocket had been decreasing by roughly four seconds per day during the month of October.

For an atmosphere like the earth's, whose density decreases markedly with elevation, the apogee distance, $a(1 + e)$, will decrease much more rapidly than the perigee distance $a(1 - e)$. The mean distance a decreases with time, the eccentricity e also decreases, but the position of the perigee is subjected by air drag to small periodic perturbations only.

Near the end of October, the apogee height of the third-stage rocket was about 500 miles, the perigee about 130, and the mean height about 315. There has not been a good separation of apogee rate from perigee rate, but the rate of change of the mean distance is well determined from the decreasing period. If the time decrease of the perigee distance was very much slower than that of apogee, as theory indicates it should be, then the apogee was falling at a rate of nearly four miles a day.

Calculations showed that the apogee would continue to descend faster and faster, until the orbit was nearly circular. Thereafter, perigee and apogee should descend at nearly equal rates, and the end of the rocket's celestial career would be near. The details of these progressive changes in the orbital elements caused by drag may yield valuable information about atmospheric densities at great heights, when analyzed by those who know the size and shape of the rockets.

40th PARALLEL CROSSINGS
1 November 1957

North-South			South-North		
EST	Longitude	Location	EST	Longitude	Location
0107	77 W	Philadelphia	0044	158 E	Pacific
0241	101 W	Ogallala, Nebr.	0219	134 E	Sea of Japan
0416	125 W	W. Coast of Calif.	0353	110 E	Peking
0550	149 W	Pacific	0528	86 E	China
0723	172 W	Pacific	0702	62 E	U.S.S.R.
0859	164 E	Pacific	0837	39 E	Turkey
1034	140 E	Japan	1011	15 E	Naples
1208	116 E	Peking	1146	9 W	Atlantic
1343	92 E	China	1320	33 W	Atlantic
1517	69 E	U.S.S.R.	1455	57 W	Atlantic
1652	45 E	Armenia	1629	81 W	Pittsburgh
1826	21 E	Greece	1804	105 W	Denver
2001	3 W	Madrid	1938	129 W	Pacific
2135	27 W	Azores	2113	153 W	Pacific
2310	51 W	Atlantic	2247	177 W	Pacific

Daily timetables of this type have been distributed to the American press by Smithsonian astronomers, to indicate in advance over what parts of the world the third-stage rocket from the first Soviet launching would pass. Each entry refers to the crossing of latitude 40° north.

Lick's 120-inch Mirror Gets Final Touches

The last stages of figuring the surface of the 120-inch telescope mirror are the slowest and most delicate. Howard Cowan watches as Don O. Hendrix presses a small hand polisher into contact. Photograph by Rulon E. Watson.

AT MT. HAMILTON in California, the time is nearing when Lick Observatory will put into operation the second largest optical telescope in the world. The giant 120-inch mirror, which will probe the depths of space scanning objects a billion and more light-years away, has reached the stage where final correcting must be done with small hand-controlled polishers. In the picture reproduced here, Don O. Hendrix and Howard Cowan are seen during the painstaking task of figuring small areas of the mirror.

Since 1953, when grinding began, about 900 pounds of glass have been removed from the original four-ton 10-foot disk of pyrex glass. But only a few thousandths of an ounce will be polished away in the final figuring to within 1/10 wave length of light (1/400,000 inch).

This delicate phase is being carried out under the personal direction of Mr. Hendrix, who is head of the optical shop at Mount Wilson and Palomar Observatories, with the assistance of Mr. Cowan, Lick Observatory optician. Mr. Hendrix has the experience needed, for he did the final figuring on the 200-inch mirror in precisely the same manner.

Hartmann and knife-edge tests are being used to find the areas of the mirror that are not perfect. For both it is necessary to have an excellent night for observing, to have the mirror in place, collecting the light of a suitable bright star. The mirror is not yet aluminized, but its five-per-cent reflectivity is sufficient for the tests. Either Mr. Hendrix or Dr. N. U. Mayall, Lick astronomer, rides in the observer's cage at the top of the telescope tube to take photographs of the test patterns.

In the Hartmann test, an opaque screen with regularly spaced holes is placed a few feet below the observer's cage, and an out-of-focus photograph is taken. Points of light on the negative show the positions of the holes; if one of these appears out of position, it indicates a distortion in the slope of the surface at a particular spot on the mirror.

The knife-edge test is carried on in much the same way that an amateur telescope maker might test a lens or mirror at focus by autocollimation, using an optical flat or parallel light from another optical system. There is no large flat mirror of sufficient size and precision to make such tests on the 120-inch mirror. Nature's own source of parallel light—the stars—must be used, though with the limitations imposed by atmospheric turbulence.

Enlargements of some of the knife-edge focograms are shown in the picture, scattered above on the mirror surface. These prints, marked to correspond to the points of the compass labeled on the edge of the disk, tell the worker where to apply the necessary corrections. A wooden ruler is used for measuring distances on the mirror itself, and the working area is outlined with the glass-marking pencil lying in front of the white box in the picture.

The hand-polishing tools are six inches in diameter or less, with a backing of pressed wood and a facing of pitch. Optical rouge is used to work the area slowly and lightly. Each spell of polishing is followed by further Hartmann and knife-edge tests to determine the results.

Mr. Hendrix is seen pressing a hand polisher on the glass to insure perfect contact before a correcting spell begins; the area is located about a foot inside the edge of the mirror in its northeast quadrant. To avoid scratches, cleanliness is of great importance. Both workers wear washable trousers with rolled-up cuffs, and washable footgear. The side of the mirror, as well as the base of the grinding and polishing machine upon which it rests, is covered with sheets of polyethylene plastic held to the mirror's edge with waterproof adhesive tape.

The supporting cores of the mirror-flotation system and the weight-reducing honeycomb structure of the mirror back are easily seen through the highly polished surface. The central hole is only eight inches in diameter, unexpectedly small for a mirror of this size.

The work necessarily goes very slowly. After a test is made, two or three days are needed to calculate where imperfections are located on the surface. A cloudy night can cause delays. One hour's work requires about a week of testing. The actual time of completion depends on the occurrence of nights of excellent seeing, which at this time of year usually are rather infrequent on Mt. Hamilton.

The 120-inch mirror has already required 300 hours for its grinding and polishing. The entire instrument, built at a cost of about 2½ million dollars to the State of California, has been 10 years in the making. A recent portrait of this optical giant and other photographs may be found in *Sky and Telescope* for December, 1956, pages 61 to 63.

Exchange of Mass in Close Binaries

OTTO STRUVE, *Leuschner Observatory, University of California*

TWO YEARS AGO, in the December issue of 1955 (page 64), we discussed five important developments during the past 10 years that have thrown new light upon the evolution of close binary systems. These developments included the work by Zdenek Kopal, of the University of Manchester, and independently by J. A. Crawford at Berkeley, on the evolutionary expansion of stars and the resulting exchange of matter between the components of such binaries. Their results had been announced at the 1954 International Astrophysical Symposium at Liege, Belgium, and in a sense reversed the trend of our thinking about the evolution of binary stars.

Ever since the historic studies by George Darwin, J. H. Jeans, and many others, astronomers habitually believed that stars steadily contracted and that important changes in their physical properties probably resulted from the contraction. But nowadays we realize that, while contraction must occur in the earliest stages of star formation, it lasts only a relatively short time. The nuclear fusion of hydrogen into helium in the deep interior of a star depletes the hydrogen there, and the energy-producing processes work their way outward. The outer layers of the star are caused to expand until it becomes a relatively cool giant or even a supergiant. The expansion stage is relatively long, so we may be able to recognize the present-day expansion of some stars.

Kopal and Crawford reasoned that in close double stars the expansion of one component would be limited by the gravitational field of the system; if the swollen star exceeded a certain well-defined upper limit it would lose its outermost layers, this material being free to move in complicated orbits from the parent star to the other one, and perhaps back again. Since the Liege symposium, Kopal has published several important papers on this subject, notably in volumes 18 and 19 of *Annales d'Astrophysique*, and in the International Astronomical Union's symposium volume, *Non-Stable Stars*. Here we shall discuss some of the highlights of Kopal's work.

Basic to Kopal's ideas is the theory of *equipotential surfaces;* when projected on the orbital plane of the binary system, these become *equipotential curves*. Such curves have been known for many years. They were used by George W. Hill in 1878 for a study of the moon's motion. They were applied to double stars by G. P. Kuiper in his 1941 discussion of moving streams of gas in the binary system Beta Lyrae, and by F. B. Wood in his 1946 work on the eclipsing binary R Canis Majoris. The meaning of these curves is illustrated in Fig. 1, which is from our article in December, 1955.

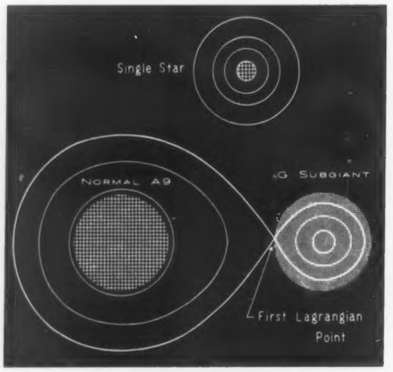


Fig. 1. Around a single star the zero-velocity or equipotential surfaces are spherical, but in a close binary they are distorted into an hourglass shape. In this example, R Canis Majoris, the G subgiant is seen to be unstable.

In Fig. 2, Kopal gives schematic representations of three principal types of close binary systems, each shown with the critical equipotential curves of the gravitational field. A particle—whether atom, meteor, or planet—that finds itself inside one or the other lobe of this figure-8 curve permanently "belongs" to the star inside that lobe, provided that the particle's velocity becomes zero when it reaches the curve. If, for any reason, the particle has a large velocity that carries it outside the curve, then its future orbit may take it away from the parent star. This can occur most easily if the particle is moving directly from one star toward the other, through the intersection point of the equipotential curves (which is called the Lagrangian point L_1). Such a particle cannot be said to belong to any one component star; it belongs to the system as a whole.

Eight different types of close binaries are illustrated in Fig. 3, part **A** corresponding to Kopal's example of stable systems in Fig. 2. The separation of the two stars is large compared with their diameters, so there is no interaction or exchange of matter going on between them.

But we know that some relatively small stars are surrounded by shells or rings of tenuous gas. In part **B**, we assume that the more massive star has such a shell, filling its lobe of the equipotential surface. If the shell is quiescent, all of it is retained gravitationally by the star. But a small disturbance, due to turbulence or thermal agitation, will permit some of the atoms to fly outside the curve. As a rule, an atom projected a short distance beyond the curve, in a direction at right angles to the line joining the stars, will return into its original home. On the other hand, a very slight disturbance at the point L_1 will propel the atom into the empty lobe surrounding the less massive star. In general, such an atom will not return but will fall into the companion star, or perhaps become part of a very tenuous ring surrounding it.

In **C**, the less massive star is assumed to have a shell of gas, from which atoms may stream through L_1 into the originally empty space surrounding the heavier star. In **D**, both stars have shells, and there may be a continuous exchange of gas between the two lobes through L_1. This configuration seems to be realized in the famous eclipsing binary Epsilon Aurigae.

Let us now suppose that the more massive star of the pair has evolved rapidly, swelling until it completely fills its equipotential lobe. Any further expansion will cause gas to escape through L_1 into the empty lobe surrounding the secondary star. I know of only one system that seems to be of this type: UX Monocerotis, shown as **E** in Fig. 3. The alternative configuration **F**—in which the less massive star has expanded while the heavier one is relatively small — is very common, and most of Kopal's work deals with such semi-detached systems. Typical examples are U Cephei, U Sagittae, and many other Algol-type variables.

Sometimes, for example, in the case of Beta Lyrae, both stars have expanded, as illustrated by **G**. The gases move rather freely through the vicinity of L_1 from one component to the other. Finally, if both stars expand still further, we obtain configuration **H**, represented by the W Ursae

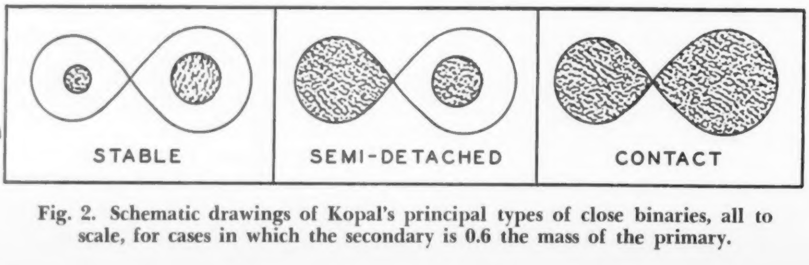


Fig. 2. Schematic drawings of Kopal's principal types of close binaries, all to scale, for cases in which the secondary is 0.6 the mass of the primary.

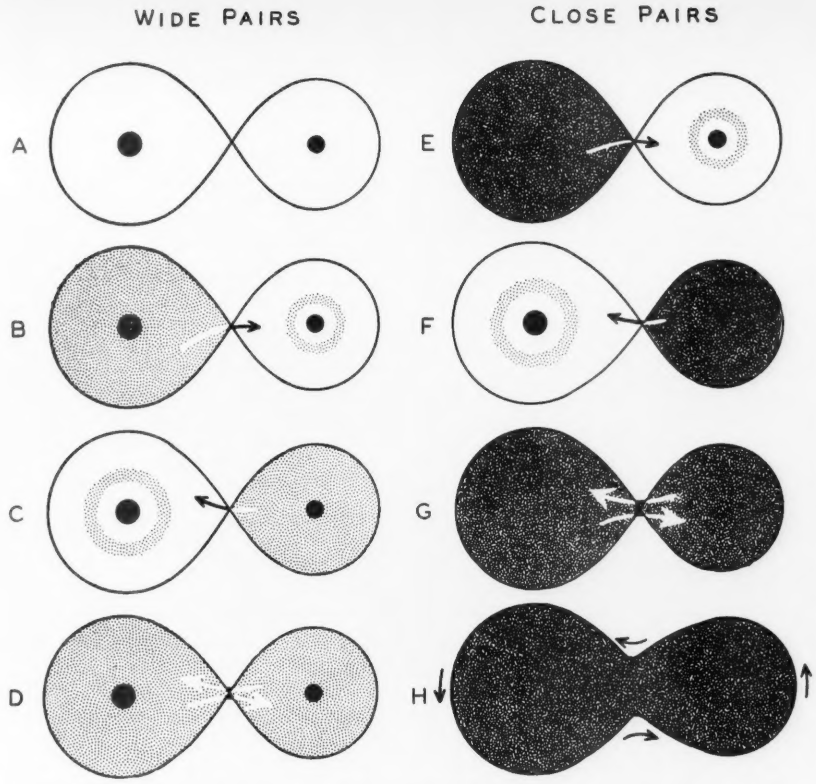


Fig. 3. Schematic drawings of eight varieties of close binaries, in all of which the secondary star has 2/3 the mass of the primary.

Majoris variables. Types **G** and **H** are known as *contact binaries.*

The significance of these equipotential curves should not be exaggerated; they are not barriers impenetrable to an expanding star, affording a sole outlet at L_1. Obviously, a rapidly rising gas cloud may, in case **G**, expel material at any point along the surface of either star. The subsequent motion of such a prominence may or may not allow it to return to the parent star. All that we may safely conclude is that it is easiest for the prominence to escape permanently from its star if it passes through L_1 or close to it.

Furthermore, gases that have passed through L_1 will not necessarily be trapped in the lobe of the companion star. If a prominence leaves the surface of the parent star at any point with a high enough velocity, it may move outward and form a vast ring of gas around the entire system. This occurs in the contact binary Beta Lyrae, according to Kuiper (see page 422, *Sky and Telescope,* July, 1957).

The motions of particles in the neighborhood of a binary star follow laws familiar in celestial mechanics. This is the *restricted problem of three bodies,* dealing with the motion of a particle of infinitesimal mass in the gravitational field of two finite masses. The path of such a particle is not a simple geometrical curve, like an elliptical orbit in the two-body problem, but it can be computed numerically step by step, if the masses of the two stars and their separation are known, together with the initial position and velocity of the particle. Kopal's work involved many such calculations, made with large electronic computers at Manchester.

Kopal has paid particular attention to case **F** in Fig. 3, which he supposes is the result of evolution of a binary system of the kind **A**, in which the less massive star has expanded until it completely fills its lobe. In his words, "The secondary components, for reasons best known to themselves, at a certain stage of their evolution begin to expand before the primaries get around to doing so."

It is probable that, when the system was of type **A**, both components rotated with the period of their orbital revolution, a synchronization such that each star always exposed the same hemisphere to the other. Then, as the secondary evolved and swelled, it had to rotate more slowly, in order to preserve its total angular momentum.

For example, the blue component of Beta Lyrae has a present rotational velocity at its equator of 45 kilometers per second, as deduced from the observed broadening of the absorption lines in its spectrum. But if this star were to rotate in exact synchronization with its 12.9-day orbital period, the rotational speed would be about 280 kilometers per second. (The latter depends on the usually accepted figure of 70 times the sun for the radius of the blue star; in the July, 1957, issue I gave reasons for suspecting that component to be smaller than this.)

According to Kopal, 12.9 days was actually the rotation period before the Beta Lyrae components began to expand. As the blue star grew, angular momentum had to be conserved, and its rotation period shortened steadily. Tidal friction is tending to lengthen the rotation, but so gradually that Kopal believes hundreds of millions of years may elapse before rotation and orbital revolution again become exactly synchronous. The time required for the expansion might be only a million years, or even less.

We can now attempt to compute the original size of the blue component of Beta Lyrae. How much has the star grown for its rotational velocity to have decreased to its present value of 45 kilometers per second? If the present radius is R and the initial radius was R', the original synchronized rotational velocity would have been 280 R'/R kilometers per second. During the expansion of the outermost layer of the star, this velocity would become smaller by the factor R'/R. Therefore,

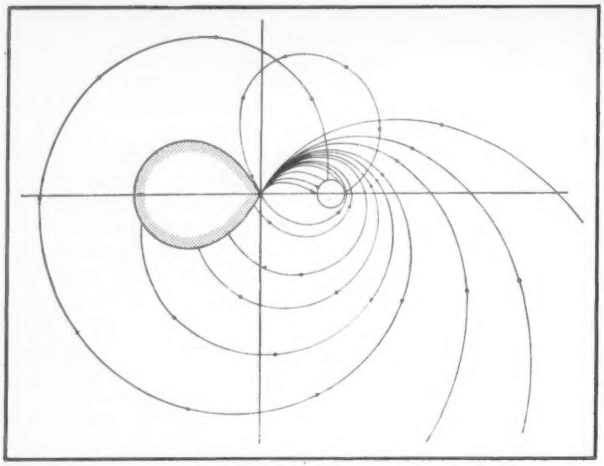
$$(R'/R)^2 = 45/280,$$

from which we see $R'/R = 1/2.5$. That is, during the expansion of the blue component of Beta Lyrae, this star has increased 2.5 times in radius, its original size having been $70/2.5 = 28$ times the sun's radius.

If, however, while the star was expanding it continued to rotate as a solid body —with consequent redistribution of angular momentum among its various layers— the change in radius would be somewhat larger. The theory of this effect was discussed by J. B. Oke and J. L. Greenstein in 1954, and it since has been applied by A. Sandage and later H. A. Abt to the related problem of single, rotating stars. It would thus seem that the original radius of Beta Lyrae may have been even smaller than 28 times the sun's.

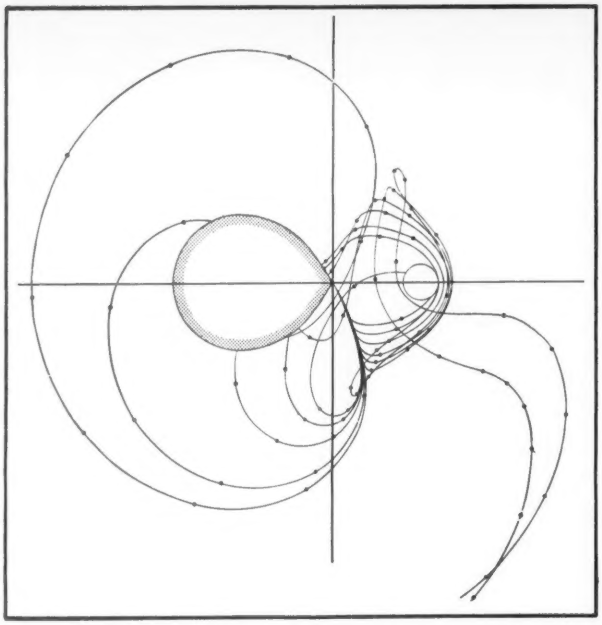
Figs. 4, 5, and 6 illustrate Kopal's recent work. The origin of co-ordinates in each case is the center of gravity of the double star system. Because the two stars are assumed to have equal masses, this center is also the Lagrangian point L_1, so that a particle located there, if subjected to no exterior force, would remain permanently. On the other hand, to remove a particle from L_1 would require less exterior force than from any other point on the surface of the expanded secondary component.

Kopal postulates that such a force might be provided by the inertia of particles on the outer layers of the secondary, because its rotation would be either faster or slower than the revolution of the system as a whole. In all his diagrams, the revolution of the system as a whole is taken to be counterclockwise. In Fig. 4, the secondary's rotation is assumed to be *faster* than the revolution, so the outermost layers will tend to slip past L_1, in a



Above: **Fig. 4. Trajectories of particles ejected with 13 different velocities into direct-moving orbits, for binaries in which the components have equal masses.**

Right: **Fig. 5. The same as Fig. 4, but for a smaller range of velocities, and for retrograde orbits.**



counterclockwise direction. (This motion is referred to a rotating system of coordinates, in which the *X*-axis is the line joining the centers of the two stars.)

Because of this slipping effect, a particle reaching L_1 will tend to move at a tangent to the equipotential surface there; it will thus slip off the secondary star with a velocity that depends on how much faster the star rotates than it revolves.

Kopal has assumed a series of different velocities at the moment of detachment of the particle at the point L_1, and has then computed the subsequent orbits of the particle in the field of the binary system. Since the equipotential curves are different for different mass ratios of the components, he has made separate calculations for a number of selected binary models in which the secondary star has a mass between 1.0 and 0.4 that of its primary. (In Fig. 3, the secondary-primary mass ratio is 2 to 3, and in Figs. 4, 5, and 6 it is 1 to 1.)

The 13 trajectories in Fig. 4 are for particles with 13 different initial velocities, over a sixfold range. It is easy to follow the effect of velocity on the particle's path: In the four slowest cases the paths end on the circle enclosing the primary's center of gravity; the next five encircle the primary, one going through L_1 again while the others lead back to the surface of the secondary; particle 10 circles both stars and ends at the primary; the highest three velocities eject the particles directly from the near neighborhood of the system, as shown by the three tracks at the right. All of these Fig. 4 orbits are called *direct* by Kopal, because they begin with a velocity that is in the same sense as the revolution of the binary system.

As we have seen, however, there is reason for assuming that most semi-detached binaries have expanding subgiant secondary stars that rotate considerably slower than would be the case if there were exact synchronization. In this event, the direction of ejection is clockwise, and the particles' orbits are *retrograde*, as illustrated in Fig. 5.

In Fig. 5, where the velocities cover only a threefold range, the six slowest particles turn toward the primary, some circling it back to the secondary; of these, particles 5 and 6 trace loops around the primary and escape from the inner system along the tracks in the lower right of Fig. 5; the remaining particles either take reversed paths to the primary or fall back on the secondary in shorter or longer orbits.

We may summarize the retrograde-orbit results, as Kopal has done, by noting that the following stages occur as the velocity of ejection through L_1 increases:

1. Many particles fall upon the primary star.
2. Other particles return to the secondary (parent) star along a path of one or more loops around the primary.
3. Still other particles return to the secondary by paths that do not enclose the primary but may enclose the secondary.
4. Some particles move around the entire system before falling back on the secondary.
5. In extreme cases, some particles escape from the system along clockwise spirals.

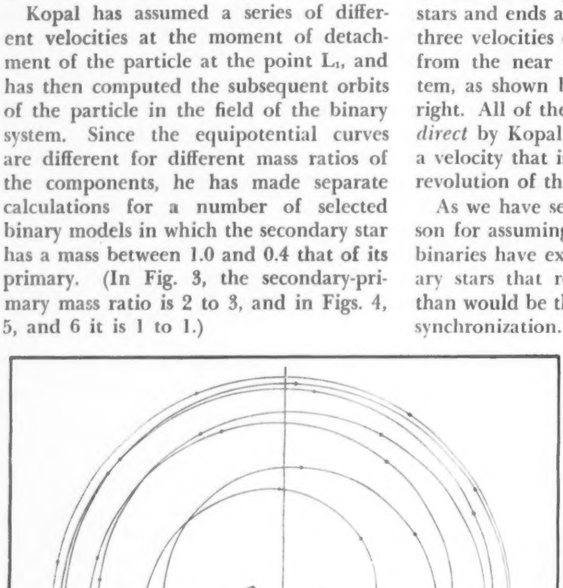


Fig. 6. The trajectory of a fast particle ejected into a retrograde orbit from the first Lagrangian point of a binary with component stars of equal masses. The scale is more compressed than in Figs. 4 and 5, and the inner parts of the trajectory can be seen in Fig. 5. All diagrams on this page are by Zdenek Kopal, reproduced from his article in the book, "Non-Stable Stars," edited by G. H. Herbig, Cambridge University Press, 1957.

For two special curves of Fig. 5 mentioned above (particles 5 and 6), Kopal has followed the orbits to much greater distances, as illustrated in Fig. 6, which is for particle 6. The recession of these particles does not continue indefinitely, but reaches a limit at a distance about 10 times as great as the radius of the orbit of the two stars; then the particle may begin to spiral inward and eventually fall back on one star or the other.

Thus, with an appropriate velocity of

(*Continued on page 93*)

NEWS NOTES

THICKNESS OF ANTARCTIC CONTINENT'S ICE LAYER

Recent IGY studies have revealed a previously unsuspected geological feature of the Antarctic continent. A 647-mile traverse made in January, 1957, showed that the thickness of the ice sheet increased from 1,950 feet, at a point 200 miles from Little America, to about 9,850 feet at Byrd Station.

The latter place, however, is at an elevation of only 4,950 feet, so the surface of the earth's crust on which the ice rests is approximately 4,900 feet below sea level. The significance of this unexpected discovery is not yet fully understood.

OPERATION MOONBEAM

Radio amateurs in the United States are setting up equipment to track American artificial satellites by means of the radio signals they will broadcast. Using a simplified, Mark II version of the primary Minitrack system, the "hams" will perform duties analogous to those of amateur astronomers under the MOONWATCH optical tracking program.

A number of articles in the September *QST*, publication of the American Radio Relay League, describe the amateur tracking program and give detailed technical information on the design and construction of the receiving apparatus. Basically, the Minitrack system uses interferometer-type radio telescopes, each consisting of antenna arrays separated from each other so that the signals they receive from the satellite are slightly out of phase. These phase differences produce alternate weakenings and reinforcements of the signal as the radiating object passes the observing station.

The same antennas—designed to receive signals broadcast by the satellites at 108 megacycles, a frequency just above the commercial FM band—can be used for radio astronomy, observing radiation from the sun, planets, radio "stars," and other emitters of cosmic noise. In fact, the amateur Minitrack stations can be calibrated with radio sources, such as Cygnus A and Cassiopeia A. In *QST*, John Firor describes the building of such a radio telescope, and Roger L. Easton gives constructional details of the antenna system for satellite tracking. While fairly complicated, this equipment is believed to be within the reach of amateur radio clubs.

Information gathered by Operation MOONBEAM is expected to be of particular importance in initially locating the satellites and in supplying data for orbit determinations. Also, at the time of a solar flare and disturbed radio propagation, telemetered data from a satellite may be missed by the main Minitrack stations, making amateur recordings very valuable. Should a satellite be damaged by meteorite impact, the time of such an event might be recorded by amateur stations.

Minitrack Mark II was developed by the Naval Research Laboratory. The program is supported by the ARRL, an organization to which most radio hams belong. Another system for the amateur, the Microlock, has been developed by the Jet Propulsion Laboratory, California Institute of Technology.

INDIANA EXPEDITION TO SOUTH AFRICA

On an expedition to South Africa in the spring of 1957, Thomas Gehrels, of Indiana University's Goethe Link Observatory, made observations of elusive solar-system objects at three large observatories. The expedition was sponsored by the National Science Foundation.

At Pretoria, with the 74-inch reflector of the Radcliffe Observatory, photoelectric observations were made of three of the Trojan asteroids. These bodies are believed to have had a common origin with Jupiter, but very little is known of their individual shapes and rotation periods. They are so faint as to be difficult to observe in even fairly large telescopes, and their motion makes them hard to find and center in the photometer eyepiece. In 1957 more Trojans, and brighter ones, were available at southern declinations than in the northern part of the sky.

With the 74-inch telescope, the brightness of three Trojans, 624 Hektor, 911 Agamemnon, and 1437 Diomedes, were found to vary during an observing night. This variation is presumably due to rapid rotation of the bodies, which therefore are not spherical and must be elongated or irregular in shape.

At Bloemfontein, with the assistance of C. Roslund, a Swedish astronomer at the internationally operated Boyden Observatory, plates were taken with the ADH Baker-Schmidt telescope in a search for new satellites of Saturn and possible "Trojan" asteroids of that planet. Even though the search was carried to a limit of about 19.5 photographic magnitude, no new satellite was found within 1½ degrees of the planet. No asteroids of the Trojan variety were found in an area of 18 square degrees, encompassing the preceding Lagrangian point of Saturn, and down to about photographic magnitude 19.0.

At Johannesburg, some 150 plates were taken jointly with J. A. Bruwer of the Union Observatory; these consisted of 75-minute exposures with the Franklin Adams camera and 20-minute exposures with the 16-inch refractor of the Leiden station. The observations were to procure positions and magnitudes of Trojans and other asteroids, in order to extend to southerly declinations the regular asteroid program of Indiana University, where Dr. Gehrels is a research associate. This, in turn, supplements the recently completed asteroid survey of Yerkes Observatory, planned to furnish new photographic magnitudes for all of the numbered asteroids.

(A list of the 33 brightest asteroids is on page 75 of this issue.)

IN THE CURRENT JOURNALS

PRECISION CELESTIAL NAVIGATION IN HIGH-SPEED, HIGH-ALTITUDE AIRCRAFT, by Major Harold F. Korger, USAF, *Navigation*, Summer, 1957. "Although celestial navigational aids have been utilized to some extent in aircraft for several decades, it is only within the past few years that the realization of reliable and precise celestial navigation has become a distinct possibility. During the past several years I have developed a precision method of practical celestial navigation that I believe to be unique. . . . Scored results have been more than encouraging, inasmuch as our 93d Bomb Wing crews have compiled the best overall celestial navigational record throughout the past four years of any organization in the annual Strategic Air Command's competition."

ARTIFICIAL EARTH SATELLITES, by V. Vakhnin, *QST*, November, 1957. "This condensation of an article that appeared in the June, 1957, issue of the U. S. S. R. publication *Radio* is timely in view of the wide interest expressed by amateurs in picking up the signals from the first satellite. It covers the general aspects of satellite travel and offers suggestions for participation by radio amateurs in the experiment. The translation is one distributed to members of the IGY technical panel on ionospheric physics."

AMERICAN ASTRONOMERS REPORT

(*Continued from page 63*)

of axial rotation, possibly coupled with turbulence in the star. The sharp-line *A* stars, nearly all of which are magnetic, may represent the small percentage of all the rapidly rotating *A* stars that happen to be viewed nearly pole-on.

All stellar magnetic fields appear to vary. Of the *A*-type stars that have been best observed, five are regular magnetic variables having periods near one week, large amplitude, and nearly symmetrical reversal of polarity. The strongest magnetic field yet found is that of 53 Camelopardalis, which varies in an eight-day period between +4,350 and −3,500 gauss. Irregular magnetic variations shown by 37 other *A* stars indicate large-scale intrinsic changes in the physical conditions at the surfaces of these stars.

Dr. Babcock has listed 65 additional stars that probably have magnetic fields, according to his observations.

ASTRONOMICAL SCRAPBOOK

Naming Some Minor Planets

OVERPRODUCTION can be as troublesome in astronomy as in industry. A prime example is provided by the asteroids that circle the sun, most of them between the orbits of Mars and Jupiter. At present, 1623 of these pocket-size planets have been given permanent identification numbers, and the addition of another makes little stir, as a rule, in the astronomical world.

At the time when only a few of these objects were known, however, the finder of a new one could count upon fame and honors. For example, the German amateur astronomer K. L. Hencke, who discovered 5 Astraea in 1845 and 6 Hebe two years later, was rewarded by the king of Prussia with a pension of $300 per annum, an adequate living then.

But as the count of known asteroids climbed into the hundreds, they became an embarrassment. Measuring their positions and, especially, the computations needed to keep these minute bodies from being lost became an ever heavier burden to astronomers, and asteroids became known as the vermin of the skies.

The strain reached the breaking point in 1891, when Max Wolf introduced mass-production photographic search methods. Long-exposure photographs with fast, large-aperture telescopes caused such a rush of new discoveries that most of them were promptly lost. Observers measuring precise asteroid positions and astronomers calculating orbits with pencil and logarithm tables could not keep pace. Only in very recent years has the use of punch-card and electronic computers ended this bottleneck.

After a newly discovered planet has its orbit reliably calculated and has been observed again at another opposition, a permanent serial number is assigned by the International Astronomical Union. The discoverer then may exercise the traditional right to name his asteroid.

All of the principal planets known from antiquity carry the names of Roman gods and goddesses, and thus the first asteroids to be discovered were named from Greek and Roman mythology. The astronomer of a century ago usually had worked through a solid classical education, and was primed with names of nymphs and other minor deities from Homer, Vergil, and Ovid.

The first minor planet was discovered on January 1, 1801, by Giuseppi Piazzi, director of the observatory at Palermo, Sicily; it bears the name of Ceres, who was not only the Roman goddess of harvests but also the special protectress of the island of Sicily. Piazzi first proposed the name Ceres Ferdinandea, to honor his royal patron King Ferdinand III of Naples, a Bourbon whose avocation was to dress in rags and sell fish in the public market of his capital city. But other astronomers refused to accept the non-mythological addition to the name.

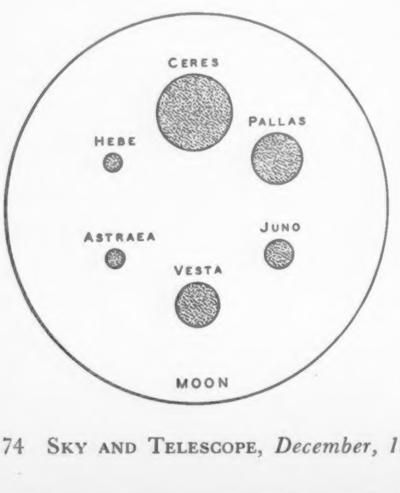
Many curious cases of this kind are collected in a recent mimeographed pamphlet, *The Names of the Minor Planets*, prepared by Paul Herget, who is director of the Cincinnati Observatory and head of the Minor Planet Center there. It contains explanations of the names of the first 342 asteroids, mostly from the historical gleanings by R. C. Cameron, formerly of Cincinnati Observatory, and A. Paluzie-Borrell, Barcelona, Spain. This small publication contains interesting footnotes to astronomical history.

Many of the asteroid names reflect half-forgotten controversies. In 1850, a London astronomer, J. R. Hind, proposed the designation Victoria for the 12th minor planet, picked up by him that September 13th. This compliment to the queen of England was strongly opposed by the American astronomers of the day, who were not averse to twisting the British lion's tail. The debate quieted when it was established that there actually had been a minor Roman divinity of the same name.

Asteroid 55 was discovered in 1858 at the Dudley Observatory, Albany, New York, during a heated dispute between its trustees and the director, B. A. Gould. This complex quarrel involved bitter newspaper charges of fraud, embezzlement, and incompetence; there were tortuous legal proceedings, "bands of hired ruffians," and even a robbery of the mails. No wonder astronomers agreed on the aptness of naming this asteroid Pandora, after the fabled owner of the box from which came all the evils that have afflicted the human race.

There is an unusual story told in connection with 139 Juewa. The first to see it was J. C. Watson, on October 10, 1874, at Peking, China. This American astronomer had gone to China to observe that year's transit of Venus, and there, as he continued his asteroid hunting, he found a slowly moving 10th-magnitude object in Pisces. "This being the first planet discovered in China," wrote Watson, "I requested Prince Kung, regent of the Empire, to give it a suitable name. In due time, a mandarin of high rank brought to me the document containing the name by which the planet should be known, coupled with a request – communicated verbally – that I would not publish the name in China until the astronomical board had communicated to the Emperor an account of the discovery and the name which had been given to the planet. This request was of course promptly acceded

Right: Giuseppi Piazzi (1746-1826) was director of Palermo Observatory, where he compiled a historic catalogue of 7,646 stars from observations between 1792 and 1813. It was while observing for this catalogue that he accidentally discovered the asteroid Ceres on the first night of the 19th century.



Left: Within a circle representing the moon (2,160 miles in diameter) are circles showing the relative sizes of the first six minor planets discovered. Even Ceres, the largest, is only 427 miles across; all the asteroids together may have less bulk than our moon.

to; and I afterwards learned upon inquiry that if the knowledge had come to the Emperor other than through the astronomical board, organized specially for his guidance in celestial matters, some of these ministers would have been disgraced. The name determined upon by Prince Kung . . . Juewa . . . means literally the Star of China's Fortune."

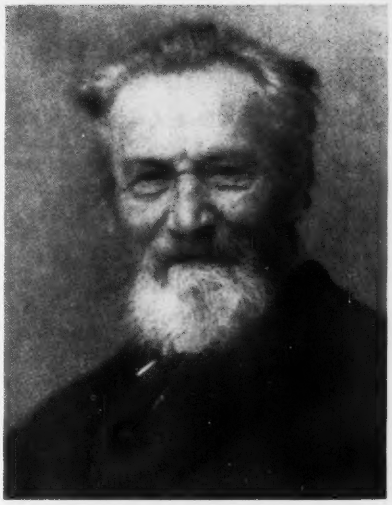
The most successful discoverer of minor planets by the slow and difficult older method of visual search was the Austrian astronomer, Johann Palisa, who found 125 asteroids between the years 1874 and 1924. His first searches were at the small observatory attached to the Austrian naval academy at Pola, near the head of the Adriatic Sea and now in Yugoslavia. The fourth of his planets discovered there, 142 Polana, honors the site.

But Palisa, who held the naval rank of commander, did not keep his professorship at this Austrian Annapolis for very long. The story is told that once, at an admiral's inspection, he appeared wearing a straw hat instead of the regulation headgear, and then strolled off peacefully to his observatory without paying his respects to the admiral. As punishment, Palisa was removed from Pola to the Vienna Observatory, where he worked happily for the rest of his long life, and became vice-director.

There was to be a total eclipse of the sun visible from Africa on August 29, 1886, and Palisa needed money for his expedition. He therefore announced that he would sell for $250 the right of naming his latest minor planet discovery. The tab was picked up by Baron Albert von Rothschild, an Austrian member of a family famed for its ready cash, who named asteroid 250 Bettina after his wife.

Many other asteroid anecdotes like these can be found in Dr. Herget's collection. It is much to be hoped that a sequel will extend it beyond minor planet 342 Endymion down to the present day, and that the entire work can be published in permanent, easily accessible form.

JOSEPH ASHBROOK



Johann Palisa (1848-1925) spent most of his scientific life observing and discovering minor planets with the 27-inch refractor of Vienna Observatory. All of his 125 discoveries were visual.

THE 33 BRIGHTEST MINOR PLANETS

FOR the 33 brightest asteroids, which have magnitudes brighter than 10.0 at average opposition, successive columns of this table list:

1. *Number,* in chronological order of discovery.
2. *Name* assigned by the discoverer.
3. *Year* of discovery.
4. *Person* and *place* of discovery.
5. *m, magnitude* at average opposition. (The planet may be considerably brighter or fainter at any specific opposition.)
6. *D, diameter* in miles as deduced from the brightness. (Most values are from K. Stumpff, *Astronomische Nachrichten, 276,* 126, 1948; the rest are rougher numbers from G. Stracke, *Astronomische Nachrichten, 273,* 24, 1942.)
7. *P, sidereal period* in years.
8. *a, semimajor axis* of the orbit (half the longest diameter of the ellipse), expressed in astronomical units of 93 million miles.
9. *e, eccentricity* of the orbit, a measure of the elongation of the ellipse. The least (perihelion) distance of the asteroid from the sun is $a(1 - e)$; the greatest (aphelion) distance from the sun is $a(1 + e)$.
10. *i, inclination* in degrees of the orbital plane to the plane of the earth's orbit.
11. *Magnitude* at the latest opposition of the asteroid to the sun.
12. *Date* of the latest opposition.

The first 16 asteroids discovered are included in this list, the first gap occurring for a fainter object, 17 Thetis. At present, the serial numbers go to 1623, and current discoveries are of faint objects, seldom brighter than magnitude 13.

No.	*Name*	*Year*	*Discoverer*	*m*	*D*	*P*	*a*	*e*	*i*	*Mag. at Latest Opp.*	
1	Ceres	1801	Piazzi, Palermo, Italy	7.4	427	4.60	2.77	0.076	10.6	7.6	Oct. 12, 1956
2	Pallas	1802	Olbers, Bremen, Germany	8.0	280	4.61	2.77	0.234	34.8	7.3	Nov. 5, 1957
3	Juno	1804	Harding, Lilienthal, Germany	8.7	150	4.36	2.67	0.258	13.0	7.1	Dec. 7, 1957
4	Vesta	1807	Olbers, Bremen, Germany	6.5	241	3.63	2.36	0.089	7.1	6.8	Oct. 11, 1957
5	Astraea	1845	Hencke, Driesen, Germany	9.9	111	4.14	2.58	0.190	5.3	10.6	Sept. 21, 1956
6	Hebe	1847	Hencke, Driesen, Germany	8.5	106	3.78	2.42	0.204	14.8	7.4	Aug. 26, 1957
7	Iris	1847	Hind, London, England	8.4	93	3.68	2.38	0.231	5.5	9.4	May 27, 1957
8	Flora	1847	Hind, London, England	8.9	77	3.27	2.20	0.157	5.9	9.8	May 19, 1957
9	Metis	1848	Graham, Markree, Ireland	8.9	135	3.69	2.39	0.124	5.6	8.8	Sept. 7, 1956
10	Hygiea	1849	de Gasparis, Naples, Italy	9.5	220	5.60	3.15	0.100	3.8	9.9	Oct. 5, 1957
11	Parthenope	1850	de Gasparis, Naples, Italy	9.3	74	3.84	2.45	0.101	4.6	9.8	March 12, 1957
12	Victoria	1850	Hind, London, England	9.7	92	3.56	2.33	0.221	8.4	8.6	Sept. 19, 1957
13	Egeria	1850	de Gasparis, Naples, Italy	9.7	122	4.14	2.58	0.086	16.5	10.1	Sept. 9, 1957
14	Irene	1851	Hind, London, England	9.7	97	4.16	2.59	0.164	9.1	10.1	Nov. 23, 1957
15	Eunomia	1851	de Gasparis, Naples, Italy	8.6	145	4.30	2.64	0.187	11.8	9.3	March 3, 1957
16	Psyche	1852	de Gasparis, Naples, Italy	9.6	200	4.99	2.92	0.139	3.1	10.3	Feb. 27, 1957
18	Melpomene	1852	Hind, London, England	9.3	82	3.48	2.30	0.218	10.1	8.3	Dec. 2, 1957
19	Fortuna	1852	Hind, London, England	9.8	99	3.82	2.44	0.158	1.5	10.0	Feb. 7, 1957
20	Massalia	1852	de Gasparis, Naples, Italy	9.2	112	3.74	2.41	0.144	0.7	8.5	Nov. 14, 1957
22	Kalliope	1852	Hind, London, England	9.8	155	4.96	2.91	0.101	13.7	9.3	Nov. 11, 1956
27	Euterpe	1853	Hind, London, England	9.7	93	3.60	2.34	0.172	1.6	9.6	Sept. 24, 1957
29	Amphitrite	1854	Marth, London, England	9.0	113	4.08	2.55	0.074	6.1	9.3	July 12, 1957
30	Urania	1854	Hind, London, England	9.9	55	3.64	2.36	0.127	2.1	9.5	Aug. 23, 1956
39	Laetitia	1856	Chacornac, Paris, France	9.5	159	4.60	2.77	0.115	10.4	9.9	Feb. 4, 1957
40	Harmonia	1856	Goldschmidt, Paris, France	9.2	55	3.41	2.27	0.046	4.3	8.9	Sept. 11, 1956
44	Nysa	1857	Goldschmidt, Paris, France	9.8	62	3.77	2.42	0.151	3.7	10.4	Aug. 16, 1956
51	Nemausa	1858	Laurent, Nismes, France	9.8	92	3.64	2.37	0.066	10.0	10.0	July 9, 1957
63	Ausonia	1861	de Gasparis, Naples, Italy	9.9	91	3.70	2.40	0.125	5.8	10.6	Jan. 21, 1957
192	Nausikaa	1879	Palisa, Pola, Austria	9.3	119	3.72	2.40	0.246	6.9	10.0	Feb. 14, 1957
324	Bamberga	1892	Palisa, Vienna, Austria	9.9	122	4.40	2.68	0.339	11.3	7.9	Nov. 1, 1956
349	Dembowska	1892	Charlois, Nice, France	9.8	159	5.00	2.93	0.089	8.3	9.5	Dec. 4, 1957
511	Davida	1903	Dugan, Heidelberg, Germany	9.6	217	5.72	3.20	0.169	15.8	9.0	Nov. 3, 1956
532	Herculina	1904	Wolf, Heidelberg, Germany	9.8	138	4.61	2.77	0.180	16.3	10.5	Nov. 8, 1957

Amateur Astronomers

Variable Star Observers Meet at Amherst

THE annual meeting of the American Association of Variable Star Observers at Amherst, Massachusetts, on October 4-6, coincided with the Soviet Union's announcement of its launching of the first artificial satellite.

Perfect weather has become a feature of the fall meetings, and this year was no exception. Only once, at New York City in 1954, did the weather fail us in recent years.

After a welcome from Dr. Albert P. Linnell, director of Amherst College Observatory, Frank M. Bateson, of Rarotonga, Cook Islands, described the work of the variable star section of the Royal New Zealand Astronomical Society. We were impressed with the wealth of observations obtained there, especially as the charts and magnitude sequences available for southern variables are much fewer than those for stars visible from northern latitudes.

The international distribution of variable star observers was emphasized by the delegates attending from widely separated places. Mr. and Mrs. Bateson came from 22° south latitude, 160° west longitude. Mr. and Mrs. Charles N. Good and Miss Isabel Williamson represented farthest north, 45°.5; while Mr. and Mrs. E. C. Melville came from Jamaica in the West Indies, 18° north latitude, 77° west longitude.

On Saturday we visited Amherst's meteorite collection, and motion pictures were shown of the 82-foot radio telescope at Bonn University Observatory, West Germany, taken by Miss W. Seitter, of Smith College. The pier of the massive dish is unique in that it contains office and laboratory space.

Following the convention banquet Saturday evening, we observed a small segment of the nearly full moon under high power through the observatory's 18-inch Clark refractor. On Sunday we traveled to Smith College for an inspection of the observatory there.

The next meeting of the AAVSO will be held June 13-15, 1958, at the Maria Mitchell Observatory on the occasion of the observatory's 50th anniversary.

DORRIT HOFFLEIT
Maria Mitchell Observatory
Nantucket, Mass.

CONTACTING NATIONAL ORGANIZATIONS

Many amateur societies are interested in establishing contact with a national organization. Further information may be obtained from the officers listed here.

American Association of Variable Star Observers. Mrs. Margaret W. Mayall, Director, AAVSO, 4 Brattle St., Cambridge 38, Mass.

American Meteor Society. Charles P. Olivier, President, American Meteor Society, 521 N. Wynnewood Ave., Narberth, Pa.

Association of Lunar and Planetary Observers. Walter H. Haas, Director, ALPO, 1203 N. Alameda Blvd., Las Cruces, N. M.

Astronomical League. Mrs. Wilma A. Cherup, Executive Secretary, Astronomical League, 4 Klopfer St., Pittsburgh 9, Pa.

Western Amateur Astronomers. Miss H. E. Neall, Permanent Secretary, WAA, 3071-A Bateman St., Berkeley 5, Calif.

EUREKA, CALIFORNIA

The Astronomers of Humboldt is a new society in Eureka, California, with a membership of 10 adults and six juniors. Interested persons should communicate with William N. Abbay, Jr., 1745 Margaret Lane, Arcata, Calif.

EDINBURG, TEXAS

The Magic Valley Astronomical Society, which is sponsored by the science division of Pan American College, has been active for one year and now has a membership of 60 amateurs. Monthly meetings are held on the third or fourth Friday at either the college or its observatory, which has a 17½-inch reflector.

The club has set up a MOONWATCH station at the observatory. Visitors are welcome, and correspondence should be addressed to the club president, Paul R. Engle, Pan American College Observatory, Edinburg, Tex.

WAYNESBORO, PENNSYLVANIA

Founded last August with 10 charter members, the Astronomical Society of Waynesboro has since grown to include 22 members, many of them coming from surrounding towns. For its primary project, the group is planning to send observers to man one of the telescopes at the MOONWATCH station in Chambersburg.

Membership is open to all amateurs over 10 years of age. The president is Robert H. Helfrick, R.F.D. 3, Waynesboro, Pa.

JUNIORS IN OKLAHOMA AND PUERTO RICO

The Oklahoma Astronomical Society of Tulsa has been formed with 26 juniors and four adults as members. The club belongs to the Astronomical League. The secretary is Larry Dicken, 1332 S. Sandusky, Tulsa 12, Okla.

Organized in June, 1956, the Amateur Astronomy Club of Caguas, Puerto Rico, now includes 15 juniors and two adults. The group meets weekly. Corresponding secretary is Juan Ramon Jiminez, Jr., Villa Blanca L-10, Caguas, Puerto Rico.

EAST CLEVELAND, OHIO

A series of open nights for the public is being held at the Warner and Swasey Observatory, Taylor and Brunswick Rds., East Cleveland 12, Ohio. The lectures begin at 8 p.m.

The topic for December 5th and 6th is "The System of Stars," and for January 16th and 17th, "The New 36-inch Telescope of the Warner and Swasey Observatory."

For reservations, call the observatory, GLenville 1-5625, between 1 and 5 p.m.

At the October meeting of the AAVSO, visiting amateur astronomer Frank M. Bateson, Cook Islands, is seen just right of center, in the dark suit. Standing at his left is Mrs. Margaret W. Mayall, director of the society. In the back row, one inch from the left edge of the picture, is Dr. Albert P. Linnell, host to the meeting and director of Amherst College Observatory. Photograph by Robert Dunn.

Miami Amateurs Televise the Moon

AN OPPORTUNITY to test the value of a live closed-circuit television pickup from a telescope, as a visual aid for teaching astronomy to large groups, was recently explored by the Southern Cross Astronomical Society, of Miami, Florida.

The tests were made with a low-priced TV camera attached to a 10½-inch f/8.5 reflector and an 8-inch f/7 reflector. The smaller telescope proved more satisfactory because of the brighter image obtained with it. The camera was arranged on a bracket with the mosaic of the vidicon pickup tube at the Newtonian focus. The instrument's driving mechanism was set to follow the moon. About 50 per cent of the lunar surface was shown at one time on the TV screen.

A coaxial cable from the telescopes, which were mounted on the roof of the Junior Museum of Miami, carried the signal to TV monitors set up in the museum's main gallery, where several hundred persons had ample views of the moon. A momentary glimpse of Saturn through clouds suggested that this planet could be televised in the same way as the moon.

Kaye Industrial Television Service provided the Dage TV camera, which sells for about $1,300 and is being used by many schools for teaching television techniques. Experiments similar to ours might be attempted by other societies.

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On the roof of the Junior Museum in Miami, technician George Feltwell operates a television camera mounted at the Newtonian focus of a reflector. Bob Miller, vice-president of the Southern Cross Astronomical Society, is at the right. The picture is relayed to monitor screens in the main gallery of the museum. Photo by Doug Kennedy, Miami "Herald."

BLAIR MEDAL AWARDED AT WESTERN CONVENTION

Mrs. Margaret W. Mayall, director of the American Association of Variable Star Observers, is the first woman to receive the G. Bruce Blair medal. The award to her was made at the ninth annual meeting of the Western Amateur Astronomers at Berkeley, California, on August 16th.

Mrs. Mayall joined the staff of Harvard Observatory in 1924 as assistant to Miss Annie J. Cannon and specialized in stellar spectroscopy. Ten years later she became affiliated with the AAVSO, and assumed the position of recorder in 1949 upon the retirement of Leon Campbell, Sr. Mrs. Mayall was Pickering memorial astronomer at Harvard during the years 1949 to 1953.

Following the presentation at the convention banquet, the 250 amateurs representing 18 western societies held a star party, utilizing many of the telescopes they brought to the meeting. Besides Saturn and some deep-sky objects, Comet Mrkos was viewed.

The next day was devoted to talks by professional and amateur astronomers. The group then motored to Lick Observatory on Mt. Hamilton, about 60 miles southeast of San Francisco. After a welcome from Dr. C. D. Shane, director of the observatory, the amateurs observed Saturn through the 36-inch refractor and also inspected the 120-inch telescope's dome.

The Eastbay Astronomical Society of Oakland was host to the convention.

On the evening of August 17th, western amateurs visited Lick Observatory on Mt. Hamilton in California. Herman Ferrier took this picture of Comet Mrkos, with some amateurs and their instruments seen silhouetted against the twilight sky. The five-minute exposure began at 8:45 p.m., Pacific standard time, on Eastman 103a-E emulsion. A 7-inch f/2.5 Aero Ektar lens was used on a clock-driven fork mounting, with a 2-inch f/18 guide telescope.

NEW SCIENCE TV PROGRAM

The Columbia Broadcasting System will begin a science television series titled "Conquest," on Sunday, December 1st, from 5 to 6 p.m. Eastern standard time. The initial telecast will deal with artificial satellites, oceanography, balloon ascents, and evolution.

THIS MONTH'S MEETINGS

Cambridge, Mass.: Amateur Telescope Makers of Boston, 8 p.m., Harvard Observatory. Dec. 12, Dr. Thomas Gold, Harvard Observatory, "The Surface of the Moon."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Dec. 13, dedication of the 36-inch reflector of the Warner and Swasey Observatory.

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., Geneva Public Library. Dec. 17, Dr. John Jamieson, University of Chicago, "The Geophysical Year To Date and Projects."

Idaho Falls, Idaho: Idaho Falls Astronomical Society, 8 p.m., O. E. Bell Junior High School. Dec. 9, Michael W. Holm, Phillips Petroleum Co., "The Use of Computers in Astronomy."

Lemont, Ill.: Argonne Astronomy Club, 8 p.m., Argonne National Laboratory. Dec. 11, Dr. John R. Huizenga, Argonne National Laboratory, "Synthesis of Elements in Stars."

Madison, Wisc.: Madison Astronomical Society, 8 p.m., Washburn Observatory. Dec. 11, James Mayland, "Winter Constellations."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Dec. 4, Dr. Winston H. Bostick, Stevens Institute of Technology, "Test-Tube Universe."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Dec. 7, Brig. Gen. Victor A. Byrnes, USAF Medical Corps, "The Human Eye."

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

SOME NOTES ON NEW AND RECENT COMETS

THE most interesting event in cometary astronomy during recent weeks has been the unexpected discovery of the fairly bright Comet 1957f. It was found at Berne Observatory, in Switzerland, on the evening of October 18th by Paul Wild, a 32-year-old Swiss astronomer who has worked at Mount Palomar. The new object was in very rapid motion toward the south and west.

Eight hours later, the new visitor was independently picked up by an American amateur, Robert Burnham, Jr., of Prescott, Arizona. (Mr. Burnham also found the Comet Bakharev-Macfarlane-Krienke 1955f two years ago, unaware it had been discovered a week earlier.) His magnitude estimate of 8 for the new comet fits better with other reports than Wild's first value of 5.

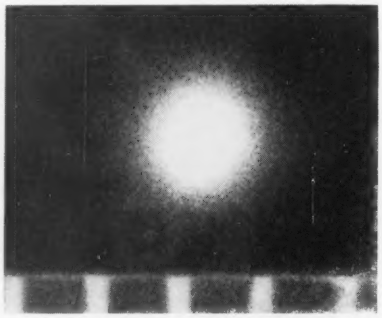
Later it became known that Comet 1957f had been observed as early as the evening of October 16th by Latyshev, at Ashkhabad in the Turkmen S. S. R.

The very rapid apparent motion of Comet Latyshev-Wild-Burnham suggested that it was passing relatively close to the earth. This surmise was confirmed by the

On August 23rd, when Comet Mrkos was in Coma Berenices, Miss Choko Fujita took this 15-minute unguided exposure with the 7.5-inch Cooke triplet at Maria Mitchell Observatory. Noteworthy details in the three main parts of the comet's multiple tail are recorded. The comet's position was very nearly the same as in the picture by R. E. Franklin on page 571 of the October issue.

preliminary orbital elements derived by the English computer M. P. Candy and reported in Harvard *Announcement Card* 1379. Mr. Candy, who assumed that the orbit was a parabola, found that the comet was to be closest to the sun—46 million miles—on December 4th. The object was fading rapidly as its distance from the earth increased; by November 2nd, according to Mr. Candy's predictions, it was in declination −37°, too far south for most United States observers.

A second comet that has recently been in the news is periodic Comet Encke.



The head of Comet Encke, a 40-minute exposure in the green light of its diatomic carbon molecules. The marks along the bottom are one minute of arc apart, or 26,000 miles at the comet's distance on September 29-30, 1957. Photograph by Freeman D. Miller with the 24-36-inch Curtis Schmidt telescope of the University of Michigan Observatory.

This famous 3.3-year comet was first observed during its current return by H. M. Jeffers at Lick Observatory, whose photograph of July 25th showed it as a diffuse 17th-magnitude object. Comet Encke brightened more rapidly than had been expected, several observers on August 24th describing it as magnitude 12 and with a head three minutes of arc in diameter. In the first week of October a further marked brightening was noted, the comet being recorded in Leo as magnitude 5 and two-tailed, just before it was lost in the morning twilight. It is possible that these changes in the comet's appearance are connected with this year's marked solar activity. No ephemeris appears to be available for Comet Encke after it passes conjunction with the sun.

Comet Arend-Roland (1956h) will be remembered as the bright naked-eye comet in the evening sky during April and May. It is still visible in very large telescopes, being during December a 15th-magnitude object a few degrees from Beta Ursae Minoris (Kochab). A new orbit for 1956h has been computed by I. Hasegawa, Shimizu, Japan, based on 116 positional observations from November 18, 1956, to June 28, 1957. The orbit turns out to be a hyperbola, with an eccentricity of 1.00023, according to *Circular* No. 1619 of the International Astronomical Union.

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54 mm (2⅛")	300 mm (11.8")	12.50	83 mm (3¼")	711 mm (28")	28.00
54 mm (2⅛")	330 mm (13")	12.50	83 mm (3¼")	762 mm (30")	28.00
54 mm (2⅛")	390 mm (15.4")	9.75	83 mm (3¼")	876 mm (34½")	28.00
54 mm (2⅛")	508 mm (20")	12.50	83 mm (3¼")	1016 mm (40")	30.00
54 mm (2⅛")	600 mm (23½")	12.50	102 mm (4")	876 mm (34½")	60.00
54 mm (2⅛")	762 mm (30")	12.50	108 mm (4¼")	914 mm (36")	60.00
54 mm (2⅛")	1016 mm (40")	12.50	110 mm (4⅜")*	1069 mm (42-1/16")	60.00
54 mm (2⅛")	1270 mm (50")	12.50	110 mm (4⅜")	1069 mm (42-1/16")	67.00
78 mm (3-1/16")	381 mm (15")	21.00	128 mm (5-1/16")*	628 mm (24¾")	75.00
80 mm (3⅛")	495 mm (19½")	28.00	128 mm (5-1/16")	628 mm (24¾")	85.00
81 mm (3-3/16")	622 mm (24½")	22.50	*Not coated		

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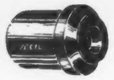

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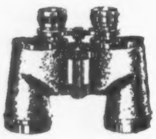
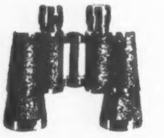


American Type



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10 x 50	"ZEISS"	30.75	28.50
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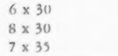

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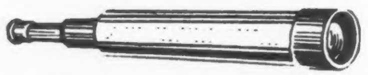

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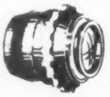

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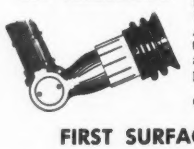

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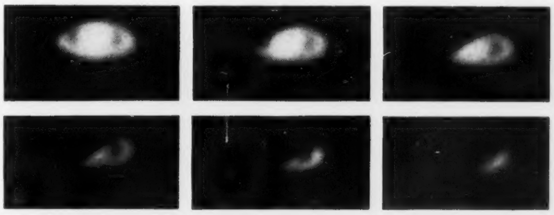
Saturn's Occultation Observed

WESTERN AMATEURS found the occultation of Saturn by the moon on the evening of August 31st a spectacle well worth watching, judging from the reports received by *Sky and Telescope*. Predictions of this event were given on page 504 of the August issue.

The occultation was a popular club and group observing activity. In Albuquerque, New Mexico, members of the high school science club watched the disappearance of the ringed planet through telescopes atop the school building, under the leadership of Mrs. Vi Hefferan.

Most of the reports came from California, where both beginning and end of the occultation were visible. Members of the Mount Diablo Astronomical Society met at their MOONWATCH station to time the phenomena. The Menifee Valley Observers were hosts to the Excelsior Telescope Club of Long Beach for this occasion, at Claude Carpenter's observatory. There the combined group viewed the immersion and emersion of Saturn through instruments ranging from a 10-inch reflector to 3-inch Zeiss binoculars.

Careful timing of the occultation was the object of Jack Harvey and Steve Marks, at North Hollywood, California, who used 6- and 8-inch reflectors, a short-wave receiver for WWV time signals, and a tape recorder. They noted that the ball of the planet began to be covered at 4:02:04 UT, and was completely covered at 4:02:56; the body of the planet began to reappear at 5:04:32 and was completely visible again at 5:05:12. These two observers noted that the appearance of Saturn matched that of the lighter lunar maria. Their observing station is at 118° 23'.4 west longitude and 34° 09'.2 north latitude, approximately.



Selected at 15-second intervals from J. E. Westfall's series of 18 photos, these show the moon moving from left to right and covering Saturn. The first picture was taken at 3:59:54 UT.

The six photographs reproduced here were obtained by J. E. Westfall, Berkeley, California, with the 20-inch refractor of Chabot Observatory. During the disappearance, ½-second exposures were made at five-second intervals, on 35-mm. Panatomic-X film at the focus of this f/16.8 telescope. The films were developed for seven minutes in DK-50. Careful microscopic examination of the original negatives gives no definite indications of unusual phenomena.

Mr. Westfall then observed visually the reappearance of Saturn with the 20-inch refractor, the seeing being fair. He found no trace of the dark band parallel to the moon's limb, sometimes reported as visible while a planet is partly covered by the moon.

In the extreme northwestern United States, Saturn escaped being occulted by the moon. Salem, Oregon, was not far from the dividing line, for R. M. Bales, who watched from there, noted that the planet cleared the northern limb of the moon by only one or 1½ minutes of arc, closest approach occurring at 4:09 UT.

Other reports of photographic and visual observations were received from R. H. Bantz, Napa, California; H. W. Brauneis, Aurora, Colorado; and Dr. J. G. Goodsell, South Pasadena, California. Mr. Brauneis photographed the event with a homemade camera that has a 2.4-inch lens and 18½-inch focal length. Dr. Goodsell tried binoculars, but found his 6-inch reflector best for observing the occultation.

DEEP-SKY WONDERS

THE COMING of winter marks the season of Orion and the varied nebulosities inside its boundaries. Within a degree of Zeta Orionis, the eastern star of the belt, lies a group of diffuse nebulae. They appear in the Mount Palomar photograph on page 531 of *Sky and Telescope* for September. Of this group, the largest is IC 434, a long wispy streak running roughly southward from Zeta. To the west of this object are patches of faint luminosity and many faint stars; to the east only a few stars are seen against what is evidently a great dark cloud.

About 30′ south of Zeta, a "bay" of dark nebulosity juts across IC 434, forming the famous Horsehead nebula. This is easily photographed, but very seldom reported visually. I have searched for it unsuccessfully many times. However, Leslie Peltier, who is the well-known comet hunter of Delphos, Ohio, mentions in a letter that he once saw it long ago. His telescope is a 6-inch refractor of about f/10, a type more common in Europe than this country, and he uses low-power oculars.

What one man can see, another can, and this winter I will try to spot the Horsehead, using a variety of telescopes. Perhaps the unusually clear air of Kansas will do the trick. Other observers are invited to write me about their results.

Beginners may prefer to try Messier 78 (NGC 2068), a diffuse nebula about 8′ by 6′ in size, located at $5^h 44^m.2$, $+0° 02'$ (1950), about two degrees above the east end of Orion's belt. Much more difficult is the faint planetary nebula NGC 2022, at $5^h 39^m.3$, $+9° 03'$, which is about 28″ in diameter.

Many amateurs never observe in Orion without spending some time with the great diffuse nebula, Messier 42, in the sword. Even the smallest telescopes show this to be a remarkable object; its grandeur may keep you half the evening. An impressive view with your lowest-power eyepiece can be obtained by first pointing the telescope a degree or two west of the bright center of the nebula. Then, with the instrument left stationary, watch the greenish nebulosity drift across the field. This procedure also helps while tracing faint outlying portions of M42.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.

Nebulae in the vicinity of Orion's belt are recorded in this red-light photograph by John C. Duncan with the 18-inch Palomar Schmidt camera. The brightest stars are those of the belt, with Zeta immersed in some of the nebulosities described here. The tiny Horsehead nebula is left of center, and the Great Nebula, M42, partly included in the lower right. Mount Wilson and Palomar Observatories photograph.

SUNSPOT NUMBERS

The following American sunspot numbers for September were derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

September 1, 224; **2,** 198; **3,** 163; **4,** 169; **5,** 165; **6,** 113; **7,** 112; **8,** 165; **9,** 186; **10,** 197; **11,** 234; **12,** 232; **13,** 226; **14,** 250; **15,** 256; **16,** 219; **17,** 214; **18,** 220; **19,** 223; **20,** 223; **21,** 232; **22,** 279; **23,** 220; **24,** 225; **25,** 219; **26,** 181; **27,** 191; **28,** 222; **29,** 211; **30,** 246. Mean for September, 207.2.

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BOOKS AND THE SKY

DISCOVERY OF THE UNIVERSE

Gerard de Vaucouleurs. The Macmillan Company, New York, 1957. 328 pages. $6.00.

THE HISTORY of astronomy is a vast subject. It has great antiquity, a brilliant renaissance, a golden classical period, the revolutionary excitement of new techniques, the wisdom and the patience of tedious work performed for future generations, and the breath-taking acceleration of all things modern.

Most historical authors have preferred to deal with only parts of this torrential stream. Gerard de Vaucouleurs has not only courageously tackled the whole subject but has succeeded extraordinarily well in presenting clearly and concisely a well-balanced and exciting picture of "the evolution of ideas" that led to "the slow strengthening of Man's intellectual grasp of the Universe in which he lives."

Discovery of the Universe is a translation of the author's 1951 work, *L'Esprit de l'Homme a la Conquete de l'Univers—L'Astronomie des Pyramides au Mont Palomar.*

The new last chapter of 74 pages, on astronomy since World War II, is representative of the entire book. It defies a complete review, since practically every sentence refers to an important astronomical study. It is no mean accomplishment to report on the work of more than 160 contemporary astronomers and still keep the material readable and well organized. Among the many important recent astronomical developments, the following brief list indicates the scope of the coverage:

1. The necessity of adopting a new unit of time.
2. The attainment of ultraviolet solar spectra from V-2 rockets.
3. The discovery of molecular hydrogen in the infrared spectra of Uranus and of Neptune.
4. The emergence of two (or more) types of stellar populations.
5. The radical change in current ideas of stellar evolution.
6. The tracing of the spiral arms of our galaxy.
7. The necessity of doubling the distance scale of the galaxies.
8. The amazing development of radio astronomy.

A few approximate statistics may help represent the character of this comprehensive book. Ancient astronomy is covered in 27 pages; the story of 16th- and 17th-century astronomers takes 26; astronomical personalities and events of the 18th and 19th centuries are covered in 112 pages; and 128 are devoted to the wonderful developments since 1900. From Copernicus to Lord Rosse the astronomers are, in general, considered individually, although biographical events are always subordinated to astronomical ideas. Other periods are organized according to subject matter. A rough tabulation shows that progress in celestial mechanics covers approximately 30 pages, studies relating to the solar system 68, stellar and galactic advances 46, and extragalactic developments 18 pages. There are 35 figures, 20 photographs, a good bibliography, and a name and subject index — all adding materially to the value of the book.

Although, among such a wealth of factual material, a few inaccuracies may be unavoidable, their presence cannot help but cast an uncomfortable shadow across the mind of the reader. For example, the page references to Claudius Ptolemy are made indiscriminately both to the famous astronomer and to the general of Alexander the Great, who became king of Egypt and who lived $4\frac{1}{2}$ centuries before the astronomer. The title of W. Struve's famous book is incorrectly given, and the quoted value for the parallax of Vega perpetuates a historical fallacy recently cleared up by O. Struve. Argelander's meridian-circle work is confused with his *Bonner Durchmusterung* work, and the limiting magnitude of the great BD catalogue is incorrectly given. A page reference listed under H. R. Morgan should have been given to W. W. Morgan. There are at least 18 similar wrong references to

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figures, plates, or other sections of the book, constituting seven per cent of all the references made.

However, in spite of these unfortunate errors of fact or of proofreading, *Discovery of the Universe* is unique for the clarity with which it follows the stream of astronomical history from its origins in antiquity to the exciting developments of last year.

HELEN PILLANS
Mills College

THEORIES OF THE UNIVERSE: From Babylonian Myth to Modern Science

Milton K. Munitz, editor. Free Press, Glencoe, Ill., 1957. 437 pages. $6.50.

ALTHOUGH not purporting to be either a textbook or a source book on cosmology, this collection comes closer to the latter. In the 437-page volume there is not a dull paragraph, and if a cosmological library had to consist of just one book, it might well be this one.

The strength of the book lies in its containing the actual words of great writers through the ages, not mere digests of their thoughts. In a few cases, such as Babylonian astronomy and medieval astronomy, excellent summarizing chapters have been reproduced from standard books. Many of the articles are not easily available elsewhere, for instance, Dreyer's tract on medieval astronomy.

There are four well-balanced sections, somewhat overlapping chronologically, each prefaced by concise, integrating remarks by the editor. In the section on ancient cosmological systems, the Greek quotations should have been literally translated, or perhaps omitted, for there is nothing scientific about them anyway—the basis of every conclusion was esthetic judgment.

The second section, on "The Classic View of a Geocentric Finite Universe," contains Plato's *Timaeus*, extracts from Aristotle's *On the Heavens*, and Ptolemy's *Almagest*. *Timaeus* is always exhilarating reading, whether one considers it the sublimest expression of metaphysical faith or the greatest scandal in the history of science! The original words of Ptolemy and Aristotle are eye openers to those contemporary readers who look upon their systems with disdain. Even by modern scientific standards, these writers were wonderfully adequate, considering the attitude of ancient thought toward observed fact.

In the third section, on the Copernican revolution and its aftermath, some authors are quoted solely to show the tendency away from geocentrism. The editor succeeds in showing the long-persisting and, on the whole, beneficial influence of Pythagoreanism in the Middle Ages, and the gradual decline of the force of esthetic judgments. Much of the pure astronomy in Copernicus' *De Revolutionibus* is entirely irrelevant to his cosmogony, but it helps us to realize the progress he made.

Kepler's article reveals his very acute yet typically medieval mind. Reaching into different spheres of knowledge, he draws far-fetched analogies, such as between the microcosm (the human body) and the macrocosm (planetary system).

A high spot of the book is the group of four letters from Newton to the Reverend Bentley. Newton lays the foundations of modern cosmology, yet his ideas of final causes are colored by concepts now abandoned. He firmly believes in the reality of substances, of inherence of qualities, mental as well as material, whereas we are now content with postulating the permanence of group relations. Nevertheless, in Newton's writings the modern mind feels at home for the first time in this long development of thought. But where lesser minds need theorems, Newton used insight. In one letter he writes about a physical field, an idea usually thought to have originated with Faraday.

The third section is marred by an error in the plate on page 166, where the moon's orbit, not that of Mars, should be drawn nearest the earth. And the diagram on page 194 does not correspond to Simplicio's description of it on the next page.

Modern theories of the universe are dealt with in the last section. The subject has made more progress since 1915 than over the entire span from the beginning of enquiry to that date. Since the field of thought has now become scientific, mathematical, and exceedingly abstruse, the editor had to sift a great mass of literature to avoid the extremes of technicality, eruditeness, and oversimplification. He succeeds in giving us the least misleading of the popular summaries and the most lucid of the technical papers by original workers in the field.

Intelligent though the general reader may be today, however, he cannot envision a world model based upon "a quadratic de Sitter line element of differential geometry containing a four-dimensional energy vector having a velocity in the time dimension and a positive divergence," unless this description is put into popular form. Thus, the general reader will find useful here only a discussion based on analogies and homely illustrations, such as Hoyle gives in the last article. In short, vivid paragraphs he unfolds a modern world picture that is perhaps the most appealing since Plato's *Timaeus*. It comes near to the layman's idea of a three-dimensional world, infinite in space and in time, both forward and backward.

In contrast, the selections include Eddington's and Lemaitre's four-dimensional expanding universes. Eddington's masterly popular style is here at its best, in dealing with one of the most easily misunderstood subjects in cosmology—four-dimensional, spherical, closed space. The two most elaborate of this last group of selections are Hubble's magnificent

summary of modern observational methods and results, and E. A. Milne's deep analysis of the foundations of science. The latter treatment is based upon Milne's own first law of motion, totally different from Newton's but as fundamental and wide in scope.

Among the recent authors there are a few inconsistencies. For instance, the rate of supernova occurrence is given as one per century per galaxy by Sciama, writing in 1955, but only one in four or five centuries by Hoyle, writing in 1950. In another 1955 paper the values of the velocity-distance relation of the galaxies prior to 1952 are used, although by 1955 they were recognized to require a correction factor of two or more.

Professor Munitz has wisely avoided changing the texts of the articles, thus preserving for us a truer view of the strengths of various arguments when they were first presented. Because there is a variety of styles, semitechnical and popular, we get the feeling of contact with the great minds of the world. He omits any summary or evaluation of his own, which is in excellent agreement with his purpose as editor.

Concurrently with the book reviewed above, the Free Press has published a companion volume by Professor Munitz, *Space, Time, and Creation,* giving his philosophical appreciation of the general trends in cosmogony through the ages. The work has 182 pages, and is priced at $3.75.

T. S. JACOBSEN
University of Washington

GALACTIC NEBULAE AND INTERSTELLAR MATTER

Jean Dufay. Philosophical Library, New York, 1957. 352 pages. $15.00.

THIS ENGLISH version of a French astronomer's textbook, reviewed in *Sky and Telescope* for February, 1955, has more the nature of a second edition than that of a translation. Like the French original, it summarizes present knowledge about matter in interstellar space in a simple, nonmathematical way understandable alike to astronomers, nonspecialized scientists, and serious amateurs. But the author has enlarged certain sections to incorporate the results of research carried out in the last few years. Even the already extensive bibliography has been augmented with 22 additional references.

Some of the numerous illustrations have been changed in size or arrangement, and one of them (Plate XXI, of Messier 8) is reproduced from a recent negative obtained by Professor Dufay himself. It is unfortunate, however, that the halftone reproductions of the new edition do not have the quality of those in the earlier one.

The translation by A. J. Pomerans is excellent, preserving the clarity of the original. However, for the professional astronomer it may be strange to read the literal translations of technical words, such as "zone of absence" instead of "zone of avoidance," and "equivalent magnitude" instead of "equivalent width" (of an interstellar absorption line).

GUIDO MUNCH
Mount Wilson and
Palomar Observatories

LE CIEL ET LA TERRE

Andre Danjon, Pierre Pruvost, and **Jules Blache,** editors. Librairie Larousse, 13 Rue du Montparnasse, Paris 6, France, 1956. 468 pages. 8,850 fr.

THIS third volume of the *Encyclopedie Francaise* is devoted to two main subjects, the sky and the earth. It contains more than 300 illustrations, photographs, colored charts, and diagrams, which deal mostly with recent observational and theoretical data.

The value of the book is undoubtedly enhanced by the fact that each specific item is treated by a well-known French expert in the field. This procedure does not affect at all the homogeneity of the text, and it guarantees a comprehensive and up-to-date description of the important aspects and basic concepts of astronomy, geophysics, and geology. The introduction states that the reader should not expect a complete treatise condensed into a few hundred pages. *The Sky and the Earth* nevertheless has a large amount of information about the great developments and discoveries in these sciences.

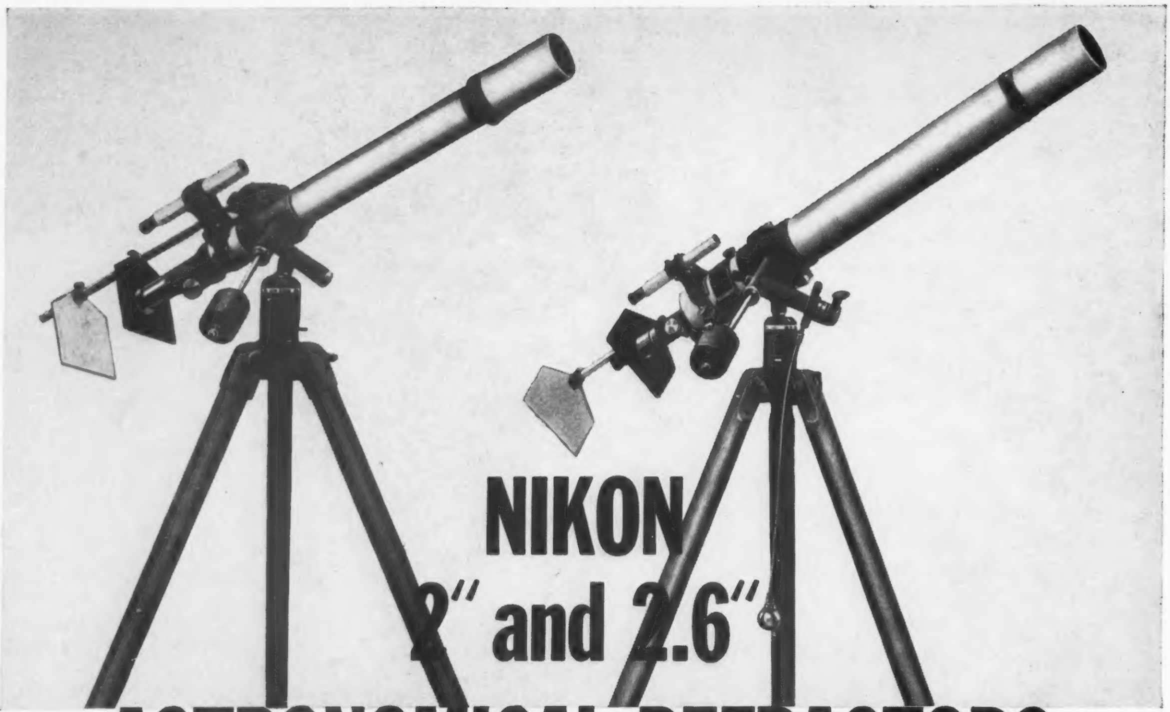
The first part of the volume is concerned with the solar system, the stars, galaxies, and cosmogony. It contains a description of past and present views dealing with the structure of the universe. Theories are discussed on the basis of facts now available through the use of powerful telescopes and precision accessories, and from the rapid advances in physics, which often go hand in hand with similar advances in astronomy.

In the second section of the book are discussed important geophysical problems concerning meteorology, aurorae, the ionosphere, terrestrial magnetism, gravity, and seismology. The earth's crust and the terrestrial surface relief are also treated.

In most of the chapters special attention is given to fundamental relations and their application to specific problems. Moreover, a comprehensive, well-subdivided list of references is appended. This makes the third volume of the French encyclopedia a valuable source of information for those who are familiar with the subjects discussed as well as for the casual reader.

The reviewer is favorably impressed by this carefully written and well-organized work.

ALBERT G. VELGHE
Royal Observatory
Uccle, Belgium



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NEW BOOKS RECEIVED

RADIOASTRONOMIE, *Raymond Coutrez,* 1956, *Patrimoine de l'Observatoire Royal de Belgique,* 3 Avenue Circulaire, Uccle, Belgium. 383 pages. 250 Belgian francs, paper bound.

Since 1952, the author has worked especially on the construction and development of the Humain-Rochefort radio astronomy station of the Royal Observatory of Belgium. This first book in French on radio astronomy is based on lectures he gave in 1955-56 at the University Foundation in Brussels. The volume is generously illustrated, and it contains 451 references to contributions in this field by astronomers of many nations.

Among the chapter subjects are the electrical circuits and special aerials used in radio astronomy, optical and radio radiation from the sun, galactic and extragalactic radio emissions, and planetary and meteoric radio studies.

FERNROHRE UND IHRE MEISTER, *Rolf Riekher,* 1957, *VEB Verlag Technik,* Unter den Linden 12, Berlin W8, East Germany. 444 pages. DM 36.

Telescopes and Their Makers is a detailed history of astronomical telescopes, from crystal lenses excavated at Troy, through Galileo, to giant refractors and reflectors, and up to Maksutov telescopes and instruments for radio astronomy. In scope it might be compared to King's *History of the Telescope.* The text, in German, is lavishly illustrated.

THE GALACTIC NOVAE, *Cecilia Payne-Gaposchkin,* 1957, *Interscience.* 336 pages. $8.50.

This monograph summarizes and evaluates the scattered data on exploding stars, as a starting point for an interpretation of the nova process. The first volume of a series in astrophysics, the book has indexes of subjects, stars, and authors, and each chapter ends with exhaustive bibliographies of published and unpublished works on the subject.

OPTICS, *Bruno Rossi,* 1957, *Addison-Wesley Publishing Co., Inc.,* Reading, Mass. 510 pages. $8.50.

A well-known professor of physics at Massachusetts Institute of Technology has written this standard textbook on optics and the phenomena of light, for use by undergraduates with training in elementary calculus. Answers to the odd-numbered problems are printed in the book, and all answers are contained in a special supplement.

RADIO ASTRONOMY, *H. C. van de Hulst,* editor, 1957, *Cambridge University Press.* 409 pages. $9.50.

In 1955, one of the International Astronomical Union's symposiums, on radio astronomy, was held at the Jodrell Bank Experimental Station, near Manchester, England. The 108 participants met in the control building of the 250-foot radio telescope under construction there (see *Sky and Telescope,* September, 1957, page 516).

The 80 papers are all in English and have been edited by H. C. van de Hulst, of Leiden Observatory. An introductory survey begins each of the book's six sections, which cover spectral-line investigations, discrete sources, galactic structure and discrete-source statistics, the sun as a quiet radio source, the active sun, meteors and planets.

New developments in antenna and receiver designs and instruments like the Mills cross are described. Scintillation and purely geophysical problems are omitted, but almost all other research in radio astronomy as of August, 1955, is covered, and some of the papers contain more recent data.

ASTRONOMISCHER JAHRESBERICHT, Vol. 55, 1957, *Astronomisches Rechen-Institut,* Grabengasse 14, Heidelberg, West Germany. 542 pages. DM 50, paper bound.

The latest volume of this standard reference work is a comprehensive listing of astronomical literature published worldwidely during 1955. The titles are arranged by subject, with each important article reference accompanied by a short abstract in German. The alphabetical subject index is in English.

PRACTICAL ASTRONOMY, *W. Schroeder,* 1957, *Philosophical Library.* 206 pages. $6.00.

Nonmathematical in its approach to astronomy, *Practical Astronomy* has diagrams and tables that aim to make active observing and the solution of problems attractive to beginners and more advanced amateurs alike. It has material on the constellations.

EXCHANGE OF MASS IN CLOSE BINARIES

(Continued from page 72)

ejection at L_1, an outer ring of gas may be formed, and these have been observed in many binary systems, including Beta Lyrae and Plaskett's star (see October issue, page 18). For a system whose total mass is three suns, with the components' centers separated by about 10 solar radii, the velocity of ejection must be of the order of 200 kilometers per second to produce such a ring. For particles to be freed entirely from the system, they must be ejected faster than the escape velocity, say, 400 kilometers per second.

Kopal has also shown that under certain conditions a particle may revolve many times around the primary before ultimately returning to its parent star. This may be a clue to the origin of gaseous rings surrounding the primary stars of many eclipsing binaries, such as RW Tauri, RW Persei, and SX Cassiopeiae. But Kopal's particular set of orbits is retrograde, whereas all the observed rings are moving the other way.

Whether the interesting vista opened by Kopal will stand the test of time remains to be seen. As was described in our July article, the slow rotation of Beta Lyrae may be explained by an entirely different hypothesis. In two other Algol-type eclipsing binaries, U Cephei and U Sagittae, the subgiant secondaries are rotating only a little more slowly than synchronization would require at the present time. For U Cephei, the period is 2.5 days and the radius of the secondary star is 2.7 million kilometers. Hence for synchronization of rotation and revolution, the rotational velocity would be about 77 kilometers per second; my spectra give 50.

In U Sagittae, the radius of the secondary is 5.4 times the sun's, and the period is 3.38 days. The expected velocity of rotation is therefore 82 kilometers per second, while the observed value is about 80. But in both systems, and also in RZ Scuti, the small primary is rotating faster than would correspond to synchronization. It may well be that the gaseous rings around the primaries have no relation to the escape of gas from the secondaries. This would agree with Kopal's views. Instead, these rings may have formed as a result of the rapid rotations of the small primaries, just as a single hot blue star may shed matter from its equator.

On the other hand, many observational facts prove the existence of gas streams from the secondaries in the general direction of their primaries. It would be of great interest to consider other mechanisms for producing these streams. One promising idea is that prominence activity on the surface of the secondary is enhanced in the vicinity of the L_1 point. Mrs. Nancy Gould is now making such calculations with the new IBM 701 electronic computer of the University of California at Berkeley.

It would also be worth while to approach the problem hydrodynamically, because in a stream of gas dense enough to produce observable absorption and emission lines, the individual atoms will interact with one another and will not travel as free particles. Their mean free paths would be too short. Allowance should also be made for the effect of radiation pressure and for the possible presence of magnetic forces.

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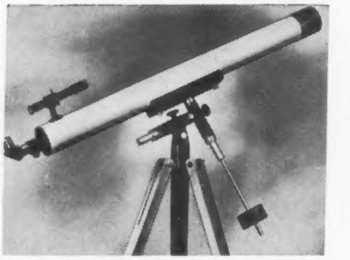

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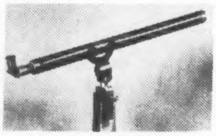

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85,008-Y	6⅞"	7⅜"	60"		4.00
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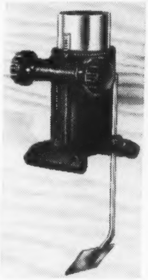

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Stock #50,077-Y (less diagonal holder)	**$9.95 ppd.**
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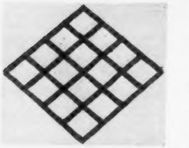
Saves Mirror Makers Time and Trouble



A rubber pitch-lap mat is used for forming the pitch-lap channels. Just pour the melted pitch on the tool, lay the mat on top and then press it in with your mirror to form the channels. When the pitch sets, an easy pull will remove the mat. In minutes instead of hours you are ready to polish. Eliminates time-consuming and tedious hand-cutting of the channels of the pitch lap.

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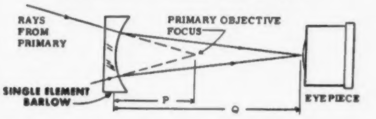
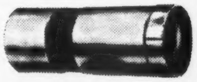


WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q!



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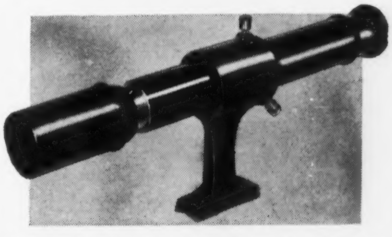
6X FINDER TELESCOPE



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AN 11-INCH MAKSUTOV TELESCOPE

THE METHOD of testing Cassegrainian secondaries outlined last month will prove a great help to amateurs constructing 11-inch Maksutov instruments through the club organized by Allan Mackintosh of Glen Cove, New York. At his request I have designed for the club a Maksutov-type telescope that can be used either as a Newtonian or a Cassegrainian.

The optical construction is shown in the diagram, while below it are the specifications for the original 11-inch design, and figures for the same telescope scaled down to 8-inch and 6-inch apertures. The description that follows is for the largest correcting lens.

Although similar to the instrument of Mr. Gregory (*Sky and Telescope,* March, 1957), the present telescope has the Newtonian focus corrected for visual use and for wide-field photography. The prime and Newtonian foci have an effective focal ratio of 4.2 and a focal length of 46.2". The amplifying ratio of the secondary is 4.82, therefore the Cassegrainian focal ratio becomes 20.24, with a resulting focal length of 222.6".

To permit photography at the prime focus, a space of 2" has been left between the focal point and the rear of the correcting lens. It is suggested that the lens be centrally perforated so the filmholder, diagonal, and Cassegrainian supporting tubes can be attached as required, thus avoiding spiders and their accompanying diffraction.

These accessories could be supported by light aluminum tubing, with a threaded bolt to go through the lens perforation, which can be fitted with a metal bushing. Such a support would be nearly 12" long for the secondary, hence the tubing should be 2" in diameter to minimize vibration. This attachment could cause some flexure of the lens in certain positions of the telescope, but I believe the system is quite tolerant of such deformation, and the support could be counterbalanced if necessary. The alternative, of course, is a spider mounting for the secondary.

Behind the regular position for the Newtonian diagonal is shown another system (dashed lines) for using this focus. The diagonal is mounted closer to the correcting lens so that approximately 1" of cone will extend outside the telescope tube. A good Barlow lens is used as an exit window and will amplify the primary focal length two or three times. This Barlow can be sealed in the tube, and an airtight plug put in the hole behind the primary mirror. It will then be possible to use a dryer-indicator for removing atmospheric moisture, in a manner similar to that described by H. H. Selby in *Sky and Telescope,* June and July, 1956.

The Cassegrainian secondary of this system, since it is fully corrected at the prime focus, must be a true hyperboloid. The test described last month should enable a perfect secondary of this type to be produced with a minimum of equipment and effort.

In that testing method, the eccentricity of the hyperboloid is calculated and a piece of optical glass is selected that has an *index of refraction numerically equal to the eccentricity.* This glass is made into a plano-convex lens with a paraxial focal length equal to the back focal length of the design. It is then tested by autocollimation from the convex side, using a suitable monochromatic light source, the knife-edge being placed at a distance equal to the back focal length from the vertex of the lens. If the surface is figured until it tests null, a perfect hyperboloidal secondary results.

Following are a number of formulae for the Cassegrainian telescope design:

$$\mathbf{A} = (\mathbf{e} + 1)/(\mathbf{e} - 1) \qquad (1)$$

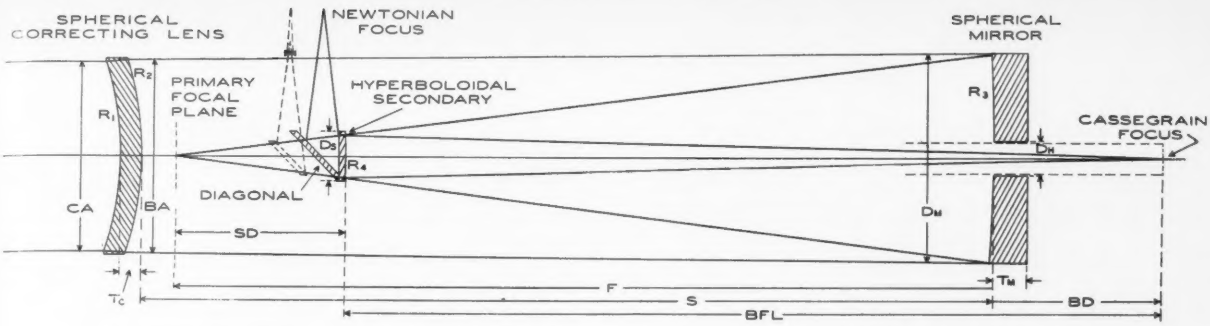
$$\mathbf{P}' = \mathbf{AP} \qquad (2)$$

$$\mathbf{e} = (\mathbf{A} + 1)/(\mathbf{A} - 1) \qquad (3)$$

$$\mathbf{R}_1 = (\mathbf{e} + 1)\mathbf{P} = (\mathbf{e} - 1)\mathbf{P}' \qquad (4)$$

Here **A** is the amplifying ratio of the secondary; **P** the distance of the secondary

MAKSUTOV TELESCOPE BY B. A. NORMAN



MAKSUTOV TELESCOPE SPECIFICATIONS

(All dimensions are in inches)

Symbol	*Characteristic*			
CA	Clear aperture of correcting lens	11.0	8.0	6.0
BA	Back aperture of correcting lens	11.25	8.18	6.14
T_c	Thickness of correcting lens	1.155	0.840	0.630
D_m	Diameter of primary mirror	12.0	8.7	6.6
T_m	Thickness of primary mirror	2.0	1.5	1.0
D_h	Diameter of hole in primary mirror	2.0	1.5	1.1
D_s	Diameter of secondary mirror	2.88	2.09	1.57
R_1	Radius of curvature of 1st lens surface	−17.094	−12.432	−9.324
R_2	Radius of curvature of 2nd lens surface	−17.747	−12.907	−9.680
R_3	Radius of curvature of primary mirror	−94.525	−68.745	−51.559
R_4	Radius of curvature of secondary mirror	−25.232	−18.350	−13.763
F	Distance from mirror to primary focus	48.226	35.073	26.305
S	Separation of lens and mirror	50.232	36.532	27.399
SD	Distance of secondary inside focus (P)	10.000	7.273	5.455
BD	Distance of Cass. focus behind primary	10.000	7.273	5.455
BFL	Back focal length (P′)	48.226	35.073	26.305
	Effective focal length of primary system	46.2	33.6	25.2
	Effective f-ratio of primary system	4.2	4.2	4.2
	Effective Cassegrainian focal length	222.6	161.9	121.4
	Effective Cassegrainian f-ratio	20.24	20.24	20.24

inside the primary focus; **P′** the back focal length of the system or the distance from the secondary mirror to the secondary focal plane; $\mathbf{R_4}$ the radius of curvature of the surface of the secondary mirror; and e the eccentricity of the hyperboloid.

Formula 3 applied to the present design gives the eccentricity of the secondary as 1.523. Examination of a catalogue of optical glass reveals that, using sodium light as a test source, C-1 optical crown has an index of just 1.5230. We require a plano-convex lens of this glass 2.88″ in diameter, with a radius on the convex surface of 25.232″. The knife-edge is placed 48.226″ from the vertex of the lens. If we test under these conditions by autocollimation, we should obtain a perfect secondary.

However, changes will be necessary if the inexpensive mercury light source described last month is used instead of sodium light. The index of C-1 crown for the 5461 mercury green line is 1.5252. Keeping the secondary's distance inside focus fixed at 10″ in the design, and applying Formula 1, we get 4.8081 as the new amplifying ratio. Using Formula 2, **P′** becomes 48.081″, or 0.145″ shorter than in the original design. The radius of the secondary, using formula 4, changes to 25.252″, or 0.020″ longer than the original. The equivalent focal ratio at the Cassegrainian focus becomes 20.19, and the focal length 222.1″.

The amateur may want to use a more commonly available optical glass, BSC-2 crown, which has an index for mercury light of 1.5190. Applying the formulae results in the following changes in design: **A** = 4.8536; **P′** = 48.536″, or 0.310″ longer than the original; $\mathbf{R_4}$ = 25.190″, or 0.042″ shorter than the original. The Cassegrainian equivalent focal ratio becomes 19.18, and the focal length 211.0″.

The ray trace of the Maksutov system

shows spherical aberration to be well within the theoretical tolerance limit. The primary limit is 0.0065", the actual 0.0024"; the secondary limit is 0.150", the actual 0.058". These figures will not be appreciably changed if BSC-2 glass is used instead of C-1; spherical aberration will still be well under the Rayleigh limit at the Cassegrain focus. However, after the secondary is perfected, small changes can be made in its figure when it is tested in conjunction with the other optical parts, and in this way we can remove any residual spherical aberration at the final focus. Coma is negligible in the primary and only slightly exceeds tolerance in the secondary system.

A rolled and welded aluminum tube is suggested, with its ends machined to take machine-turned cells for the corrector and primary mirror. If high-quality optical and mechanical effort is put into the project, a superior instrument should result.

BURT A. NORMAN
Franklin Center
Quebec, Canada

A VACUUM FILM CONTAINER

IN 1924, when I was living near the Oregon coast, where the weather is warm and very moist, I tried my hand at celestial photography. Film storage turned out to be a major problem.

I tried placing the films and plates in a container with dried blotting paper, but this was not satisfactory. Observatory astronomers suggested a two-part can, with the lower part filled with dried tea leaves, roasted rice, or silica gel. The last proved most practical, but was a bother on long trips, and that was my real problem.

In 1952, after I had an encounter with a black widow spider, I made a snake-bite suction cup operated by a hose on the vacuum swipe of my automobile. As the intake manifold suction at sea level is about 22 inches of mercury when the engine is idling, I thought of using this method to pump out an airtight tank for film storage. The tank I built is pictured here. Instead of emptying this chamber by the automobile manifold, it may be evacuated to about 20" suction with a few strokes of a bicycle-tire pump with the piston leather reversed, or to about 10" simply by sucking on the end of the hose.

The cylinder is made from 6" aluminum pipe, 24" long. Each end was turned with a lathe, and at the same time threaded on the inside with 24 threads to the inch. A gasket of "port gum" 1/16" thick is used to seal the aluminum heads, which are also lubricated. While it is not essential, the vacuum gauge is well worth its cost of $2.12.

I keep the vacuum recorded on the gauge between 15" and 20". When set aside at 20", the gauge comes up to 15" in about 10 days. During the five-year test described below, these limits were maintained.

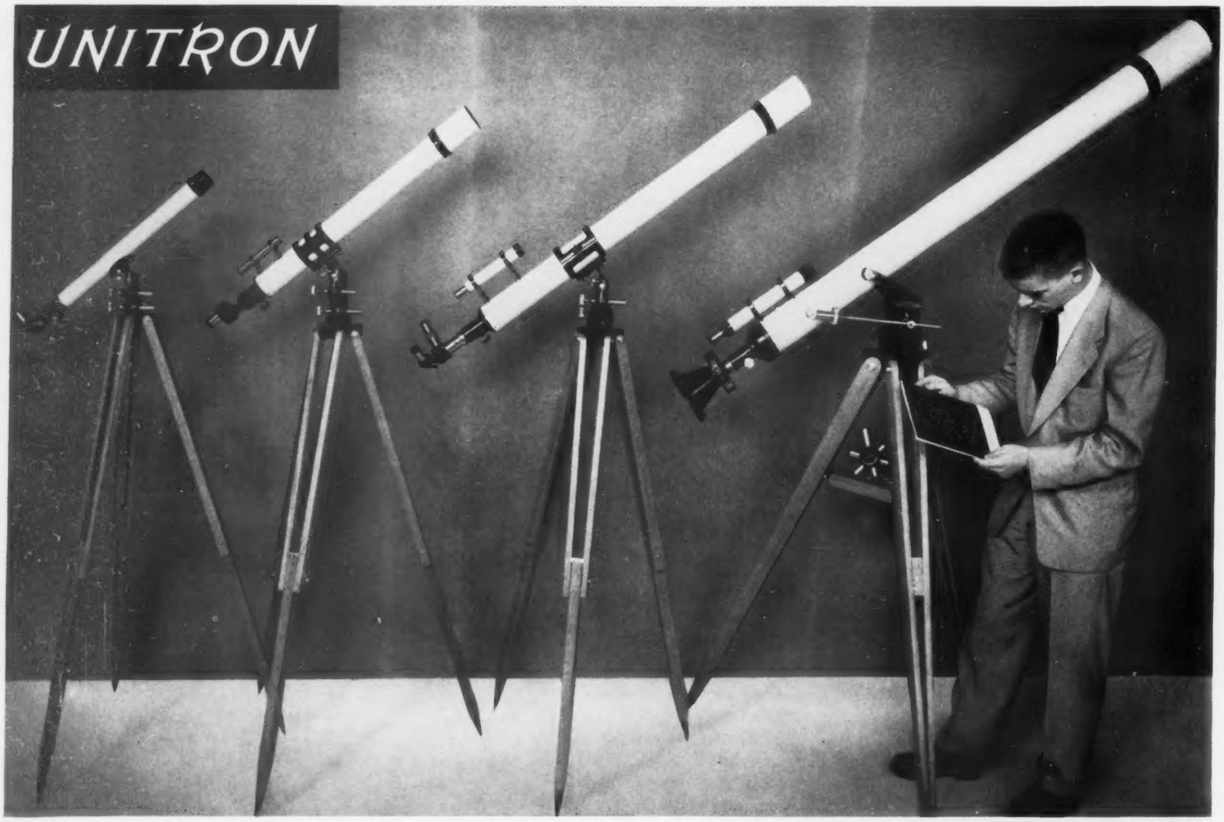
Five years ago, I exposed half a roll of 16-mm. Kodachrome movie film, half a roll of 35-mm. Kodachrome, and the same in black and white. Four sheets of black-and-white film were exposed and put with four unexposed sheets. All of these were placed in a container with silica gel. A duplicate set was placed in the vacuum chamber.

Whenever the vacuum container was opened, the other container was opened for the same length of time. The gel was dried whenever convenient. This year, I exposed all the film and had it processed. The contents of the container with the gel were a total loss. Those of the vacuum container were normal, as far as I could tell.

Both containers had been exposed to temperatures between 13° and 116° Fahrenheit, relative humidities from 6% to 98%, and both were opened numerous times under these extreme conditions.

W. C. CHENEY
Box 3591, Seattle 24, Wash.

Fred Wolfenden demonstrates the use of the vacuum chamber designed by W. C. Cheney for film storage. The cover for the vacuum chamber is seen at the lower left; it carries a suction connection and an inexpensive suction gauge.



UNITRON Altazimuth Refractors: left to right, 1.6" (with star diagonal), 2.4" (with erecting prism system), 3" (with DUETRON double eyepiece), and 4" (with astro-camera and with UNIHEX on the shelf).

UNITRON Equatorial Refractors: left to right, 2.4" (with astro-camera), 3" Photo-Equatorial (with sun screen), and 4".

CELESTIAL CALENDAR

Universal time is used unless otherwise noted.

MOON PHASES AND DISTANCE

Full moon	December 7, 6:16
Last quarter	December 14, 5:45
New moon	December 21, 6:12
First quarter	December 29, 4:52
Full moon	January 5, 20:09

	December	Distance	Diameter
Perigee	14, 5^h	230,100 mi.	32′ 16″
Apogee	28, 4^h	251,300 mi.	29′ 33″
	January		
Perigee	9, 0^h	227,600 mi.	32′ 37″

DECEMBER METEORS

December is marked by four world days of the International Geophysical Year, and all of these are of special importance to meteor observers, as related by Dr. Peter M. Millman in the May, 1957, issue of *Sky and Telescope,* page 317. The corresponding observation nights are December 12-13, 15-16, 20-21, and 21-22. Instructions and report forms for those who would like to participate in the organized IGY meteor observing program can be obtained from the Meteor Centre, IGY, National Research Council, Ottawa, Ontario, Canada.

The Geminids, second strongest meteor shower of the year, reach their maximum on December 13th, at 12^h UT, with some shower members observable for a few days before and after that date. The last-quarter moon will not interfere, as the Geminids are strong before midnight. Under favorable conditions, up to 40 meteors per hour may be seen by a single observer. The Geminids are bright, of medium speed, and radiate from a point near Castor, at right ascension 7^h 32^m, declination +32°.

Later in the month, the December Ursids will appear, with a predicted rate of up to 15 meteors per hour. The maximum is scheduled for December 22nd, at 17^h UT, and the radiant is near the bowl of the Little Dipper, at 14^h 28^m, +76°.

OCCULTATION PREDICTIONS

December 15-16 **Alpha Virginis** 1.2, 13:22.9 −10-56.2, 25. Im: **A** 9:12.8 −0.8 +0.4 114; **B** 9:13.7 −0.8 +0.7 107; **C** 9:09.0 −0.5 −0.1 130; **D** 9:08.5 −0.6 +0.4 118; **E** 9:04.3 −0.1 −0.4 141. Em: **A** 10:22.5 −1.2 +0.1 295; **B** 10:14.9 −1.1 +0.5 290; **C** 10:15.1 −1.4 +0.7 280; **D** 10:21.6 −1.0 +0.1 302; **E** 9:59.5 −1.0 +1.4 266.

December 22-23 **Beta Capricorni** 3.2, 20:18.6 −14-55.1, 3. Im: **A** 22:47.8 −0.6 −0.5 62; **B** 22:46.1 −0.5 −0.3 52; **C** 22:46.1 −0.9 −0.5 67; **D** 22:43.0 −0.7 −0.1 51. Em: **E** 23:42.7 −1.1 −1.2 268; **F** 23:40.7 −1.3 −0.2 250.

December 23-24 **Nu Aquarii** 4.5, 21:07.3 −11-32.8, 4. Im: **A** 22:52.5 ... ... 3; **C** 22:43.7 −0.1 +2.4 12.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo,** lat. **L**) within 200 or 300 miles of a standard station (long. **LoS,** lat. **LS**). Multiply **a** by the difference in longitude (**Lo — LoS**), and multiply **b** by the difference in latitude (**L — LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

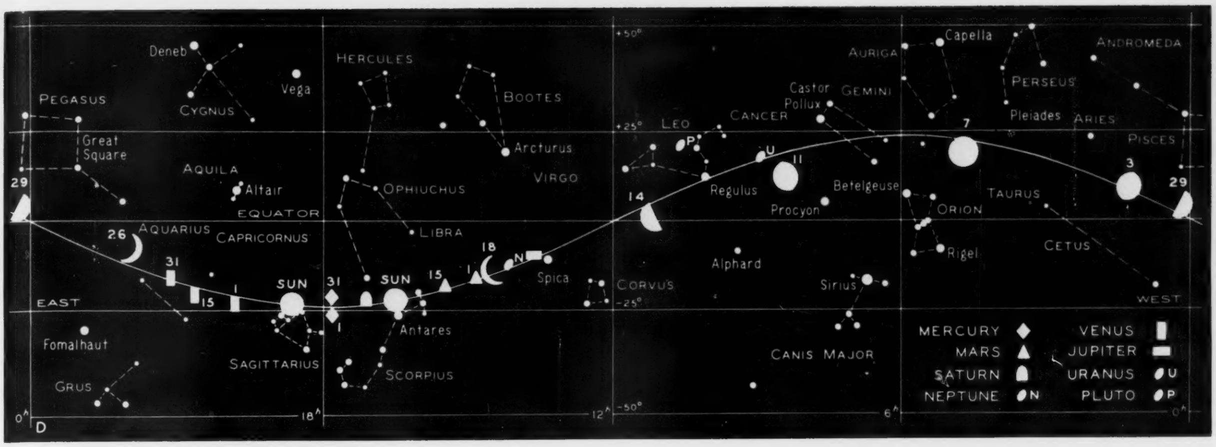
A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

VARIABLE STAR MAXIMA

December 2, R Andromedae, 001838, 7.0; 2, T Ursae Majoris, 123160, 7.9; 5, R Draconis, 163266, 7.6; 5, R Horologii, 025**050,** 6.0; 8, S Canis Minoris, 072708, 7.5; 9, RR Scorpii, 165**030,** 6.0; 19, R Aquarii, 2338**15,** 7.3; 19, W Lyrae, 181136, 8.0; 27, X Monocerotis, 065**208,** 7.6; 27, S Pictoris, 050**848,** 8.0; 29, U Cygni, 201647, 7.6; 29, R Hydrae, 132**422,** 4.6.

January 2, S Sculptoris, 001**032,** 6.8.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0^h Universal time on the respective dates.

Mercury reaches greatest elongation on December 8th, 20° 58′ east of the sun, when its magnitude is −0.1. It will set $1\frac{1}{4}$ hours after the sun at that time, and may be followed for another week before disappearing into the sun's glare. Inferior conjunction occurs on the 25th.

A close conjunction may be observed on December 7-8, as Mercury passes about 2′ south of Lambda Sagittarii, a 3rd-magnitude star.

Venus will be a striking object each evening after sunset throughout December. On the 1st, it shines at magnitude −4.2 and sets three hours after the sun. Greatest brilliancy of −4.4 occurs the day before Christmas, when the planet is practically as bright as it can ever be.

Telescopically, the planet is seen as a crescent, growing slimmer but larger. At the beginning of the month, Venus' disk is 29″.4 in diameter and 43-per cent illuminated. By the 31st, the apparent size will be 46″, disk illumination 20 per cent —a striking crescent in a small telescope.

Earth arrives at heliocentric longitude 90° on December 22nd at 2:49 UT. Winter commences in the Northern Hemisphere and summer in the Southern.

Mars travels rapidly eastward in Libra and Scorpius, having the appearance of a reddish 2nd-magnitude star. The planet rises about $2\frac{1}{2}$ hours before the sun by the end of the month.

Jupiter rises five hours before the sun at midmonth, and shines brightly at magnitude −1.4. It is moving slowly eastward in Virgo, near Spica.

Saturn passes conjunction with the sun on December 9th, entering the morning sky. It is too close to the sun to be observed.

Uranus can be viewed after 10 p.m. local time in mid-December. It is moving westward, about 4° east of Delta Cancri, and is of the 6th magnitude.

Neptune rises about four hours before the sun in midmonth. This 8th-magnitude object is moving very slowly eastward, about 2° south of Kappa Virginis.

CORRECTIONS TO PAGE 71

In this issue of *Sky and Telescope*, page 71, third column, line 9, change "shortened" to "lengthened," and line 10, change "lengthen" to "shorten."

MINIMA OF ALGOL

December 1, 2:14; 3, 23:03; 6, 19:52; 9, 16:41; 12, 13:30; 15, 10:19; 18, 7:08; 21, 3:58; 24, 0:47; 26, 21:36; 29, 18:25. January 1, 15:14; 4, 12:03; 7, 8:53; 10, 5:42.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

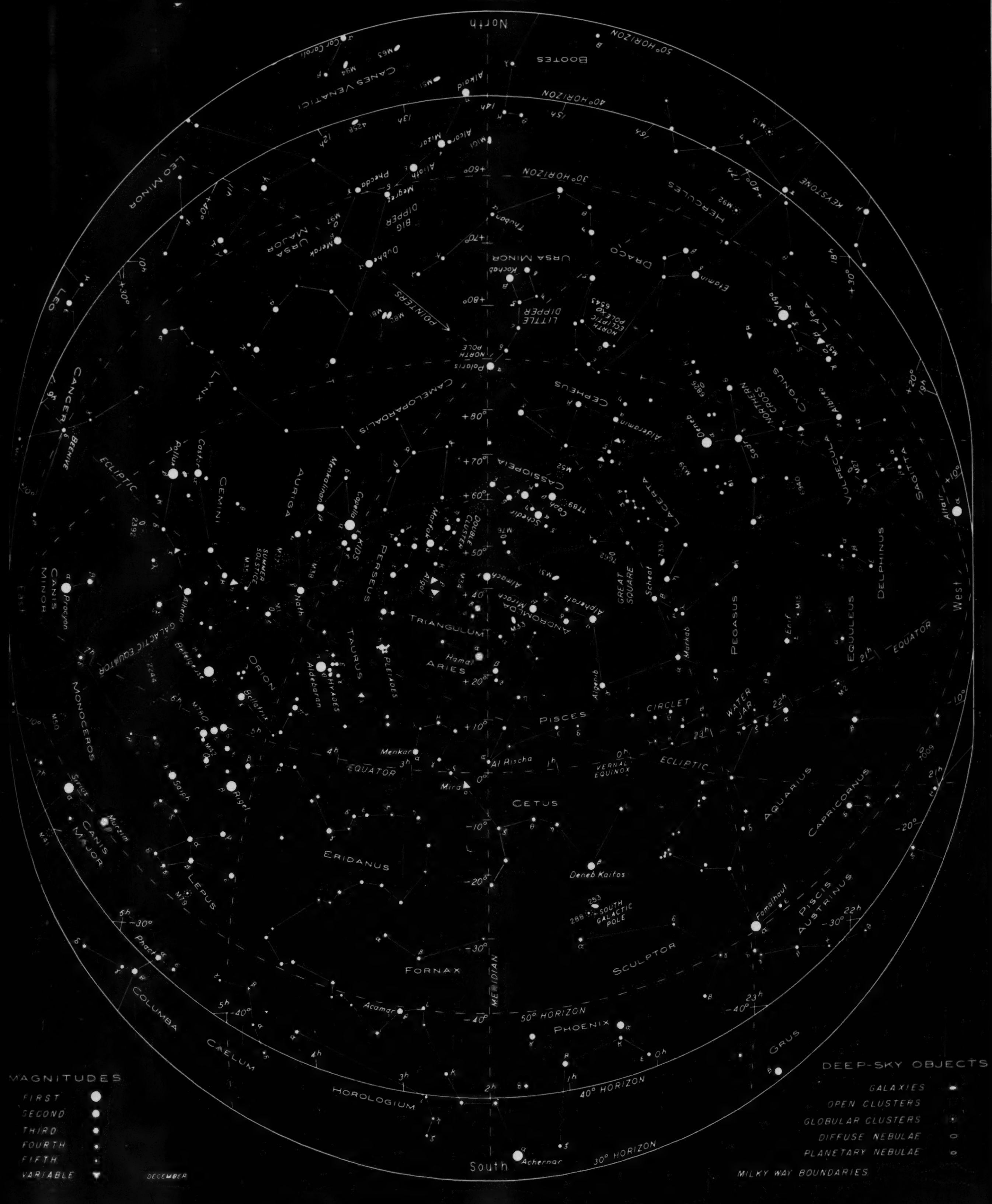
UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 5th and 21st of February; also, at 9 p.m. and 8 p.m. on March 7th and 23rd. For other dates, add or subtract ½ hour per week.

Fifteen 1st-magnitude stars are visible in the sky at chart time for all except the most southerly observers: Sirius, Canopus, Alpha Centauri, Capella, Rigel, Procyon, Achernar, Beta Centauri, Betelgeuse, Aldebaran, Alpha Crucis, Spica, Pollux, Beta Crucis, and Regulus.



STARS FOR DECEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of December, respectively; also, at 7 p.m. and 6 p.m. on January 7th and 23rd. For other dates, add or subtract ½ hour per week.

High in the December sky we find the Royal Family – Cepheus, Cassiopeia, and Andromeda. Here, too, are Cetus the sea monster, and Perseus. These five constellations immortalize the myth of an ancient queen's vanity and the heroic rescue of a beautiful maiden.

UNITRON INSTRUMENT DIVISION of UNITED SCIENTIFIC CO.